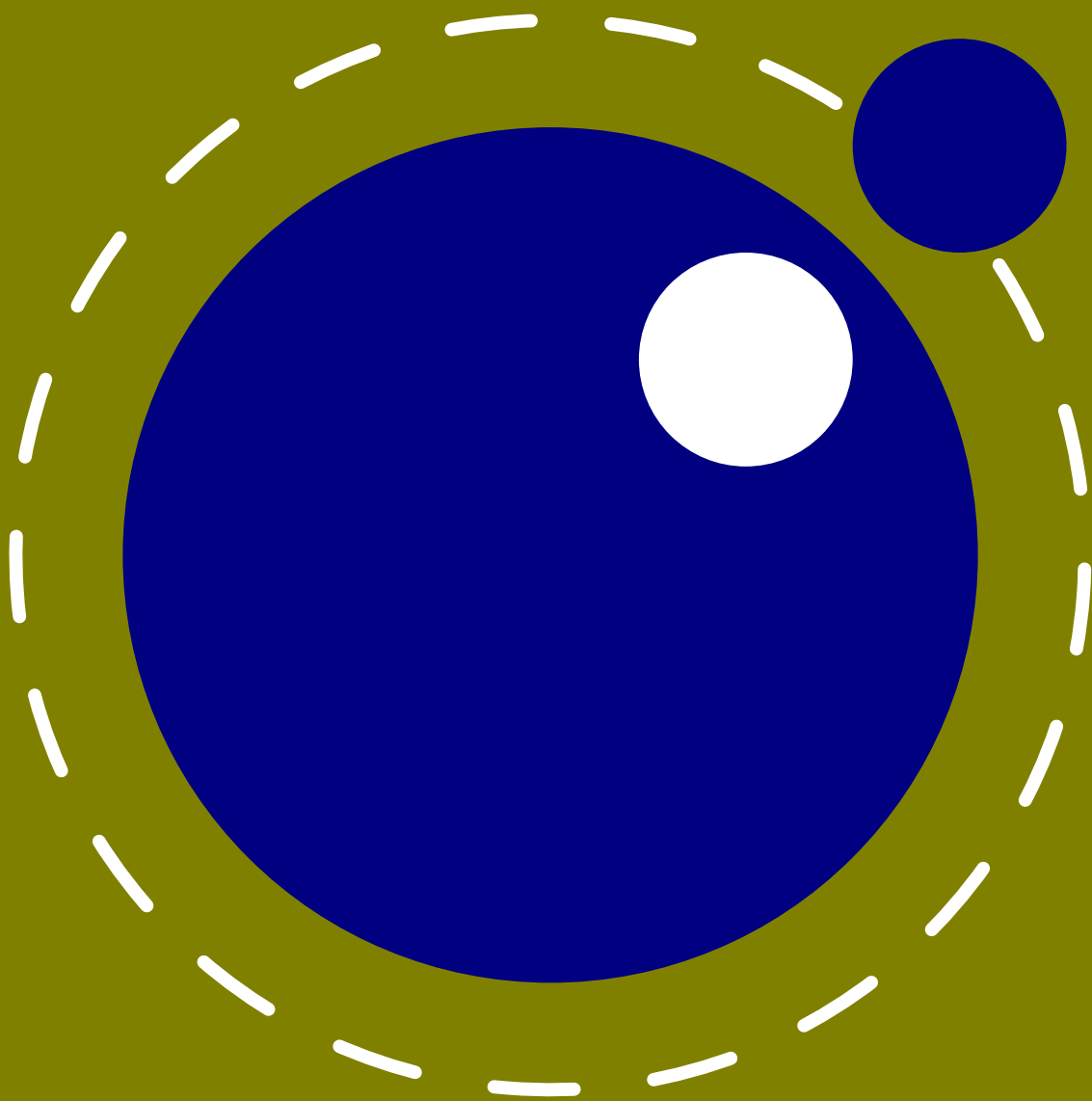


LuaTeX

Reference

Manual



stable
February 2025
Version 1.21

LuaTeX

Reference

Manual

copyright : LuaTeX development team
more info : www.luatex.org
version : February 10, 2025

Contents

| | |
|--|-----------|
| Introduction | 15 |
| 1 Preamble | 19 |
| 2 Basic TeX enhancements | 21 |
| 2.1 Introduction | 21 |
| 2.1.1 Primitive behaviour | 21 |
| 2.1.2 Version information | 21 |
| 2.2 UNICODE text support | 22 |
| 2.2.1 Extended ranges | 22 |
| 2.2.2 <code>\Uchar</code> | 23 |
| 2.2.3 Extended tables | 23 |
| 2.3 Attributes | 23 |
| 2.3.1 Nodes | 23 |
| 2.3.2 Attribute registers | 24 |
| 2.3.3 Box attributes | 24 |
| 2.4 LUA related primitives | 25 |
| 2.4.1 <code>\directlua</code> | 25 |
| 2.4.2 <code>\latelua</code> and <code>\lateluafunction</code> | 27 |
| 2.4.3 <code>\luaescapestring</code> | 27 |
| 2.4.4 <code>\luafunction</code> , <code>\luafunctioncall</code> and <code>\luadef</code> | 27 |
| 2.4.5 <code>\luabytcode</code> and <code>\luabytcodecall</code> | 28 |
| 2.5 Catcode tables | 29 |
| 2.5.1 Catcodes | 29 |
| 2.5.2 <code>\catcodetable</code> | 29 |
| 2.5.3 <code>\initcatcodetable</code> | 29 |
| 2.5.4 <code>\savecatcodetable</code> | 29 |
| 2.6 Suppressing errors | 30 |
| 2.6.1 <code>\suppressfontnotfounderror</code> | 30 |
| 2.6.2 <code>\suppresslongerror</code> | 30 |
| 2.6.3 <code>\suppressifcsnameerror</code> | 30 |
| 2.6.4 <code>\suppressoutererror</code> | 30 |
| 2.6.5 <code>\suppressmathparerror</code> | 30 |
| 2.6.6 <code>\suppressprimitiveerror</code> | 31 |
| 2.7 Fonts | 31 |
| 2.7.1 Font syntax | 31 |
| 2.7.2 <code>\fontid</code> and <code>\setfontid</code> | 31 |
| 2.7.3 <code>\noligs</code> and <code>\nokerns</code> | 31 |
| 2.7.4 <code>\nospaces</code> | 32 |
| 2.8 Tokens, commands and strings | 32 |
| 2.8.1 <code>\scantextokens</code> | 32 |
| 2.8.2 <code>\toksapp</code> , <code>\tokspre</code> , <code>\etoksapp</code> , <code>\etokspre</code> , <code>\gtoksapp</code> , <code>\gtokspre</code> , <code>\xtoksapp</code> , <code>\xtokspre</code> | 32 |
| 2.8.3 <code>\csstring</code> , <code>\begincsname</code> and <code>\lastnamedcs</code> | 33 |



| | | |
|----------|---|-----------|
| 2.8.4 | <code>\clearmarks</code> | 33 |
| 2.8.5 | <code>\alignmark</code> and <code>\aligntab</code> | 33 |
| 2.8.6 | <code>\letcharcode</code> | 33 |
| 2.8.7 | <code>\glet</code> | 34 |
| 2.8.8 | <code>\expanded</code> , <code>\immediateassignment</code> and <code>\immediateassigned</code> | 34 |
| 2.8.9 | <code>\ifcondition</code> | 35 |
| 2.9 | Boxes, rules and leaders | 36 |
| 2.9.1 | <code>\outputbox</code> | 36 |
| 2.9.2 | <code>\vpack</code> , <code>\hpack</code> and <code>\tpack</code> | 36 |
| 2.9.3 | <code>\vsplit</code> | 36 |
| 2.9.4 | Images and reused box objects | 36 |
| 2.9.5 | <code>\nohrule</code> and <code>\novrule</code> | 37 |
| 2.9.6 | <code>\gleaders</code> | 37 |
| 2.10 | Languages | 37 |
| 2.10.1 | <code>\hyphenationmin</code> | 37 |
| 2.10.2 | <code>\boundary</code> , <code>\noboundary</code> , <code>\protrusionboundary</code> and <code>\wordboundary</code> | 38 |
| 2.10.3 | <code>\glyphdimensionsmode</code> | 38 |
| 2.11 | Control and debugging | 38 |
| 2.11.1 | Tracing | 38 |
| 2.11.2 | <code>\outputmode</code> | 38 |
| 2.11.3 | <code>\draftmode</code> | 39 |
| 2.12 | Files | 39 |
| 2.12.1 | File syntax | 39 |
| 2.12.2 | Writing to file | 39 |
| 2.13 | Math | 39 |
| 3 | Modifications | 41 |
| 3.1 | The merged engines | 41 |
| 3.1.1 | The need for change | 41 |
| 3.1.2 | Changes from T _E X 3.1415926 | 41 |
| 3.1.3 | Changes from ϵ -T _E X 2.2 | 42 |
| 3.1.4 | Changes from PDFT _E X 1.40 | 42 |
| 3.1.5 | Changes from ALEPH RC4 | 45 |
| 3.1.6 | Changes from anywhere | 46 |
| 3.1.7 | Changes from standard WEB2C | 46 |
| 3.2 | The backend primitives | 46 |
| 3.2.1 | Less primitives | 46 |
| 3.2.2 | <code>\pdfextension</code> , <code>\pdfvariable</code> and <code>\pdffeedback</code> | 47 |
| 3.2.3 | Defaults | 52 |
| 3.2.4 | Backward compatibility | 52 |
| 3.3 | Directions | 54 |
| 3.3.1 | Four directions | 54 |
| 3.3.2 | How it works | 54 |
| 3.3.3 | Controlling glue with <code>\breakafterdirmode</code> | 56 |
| 3.3.4 | Controlling parshapes with <code>\shapemode</code> | 56 |
| 3.3.5 | Symbols or numbers | 57 |



| | | |
|----------|--|-----------|
| 3.4 | Implementation notes | 58 |
| 3.4.1 | Memory allocation | 58 |
| 3.4.2 | Sparse arrays | 58 |
| 3.4.3 | Simple single-character csnames | 58 |
| 3.4.4 | The compressed format file | 59 |
| 3.4.5 | Binary file reading | 59 |
| 3.4.6 | Tabs and spaces | 59 |
| 3.4.7 | Hyperlinks | 59 |
| 4 | Using L^AT_EX | 61 |
| 4.1 | Initialization | 61 |
| 4.1.1 | L ^A T _E X as a Lua interpreter | 61 |
| 4.1.2 | L ^A T _E X as a Lua byte compiler | 61 |
| 4.1.3 | Other commandline processing | 61 |
| 4.2 | Lua behaviour | 64 |
| 4.2.1 | The Lua version | 64 |
| 4.2.2 | Integration in the TDS ecosystem | 65 |
| 4.2.3 | Loading libraries | 65 |
| 4.2.4 | Executing programs | 65 |
| 4.2.5 | Multibyte string functions | 66 |
| 4.2.6 | Extra os library functions | 67 |
| 4.2.7 | Binary input from files with <code>fio</code> | 69 |
| 4.2.8 | Binary input from strings with <code>sio</code> | 69 |
| 4.2.9 | Hashes conform sha2 | 69 |
| 4.2.10 | Locales | 70 |
| 4.3 | Lua modules | 70 |
| 4.4 | Testing | 70 |
| 5 | Languages, characters, fonts and glyphs | 73 |
| 5.1 | Introduction | 73 |
| 5.2 | Characters, glyphs and discretionaries | 73 |
| 5.3 | The main control loop | 79 |
| 5.4 | Loading patterns and exceptions | 81 |
| 5.5 | Applying hyphenation | 83 |
| 5.6 | Applying ligatures and kerning | 85 |
| 5.7 | Breaking paragraphs into lines | 87 |
| 5.8 | The lang library | 87 |
| 5.8.1 | <code>new</code> and <code>id</code> | 87 |
| 5.8.2 | <code>hyphenation</code> | 88 |
| 5.8.3 | <code>clear_hyphenation</code> and <code>clean</code> | 88 |
| 5.8.4 | <code>patterns</code> and <code>clear_patterns</code> | 88 |
| 5.8.5 | <code>hyphenationmin</code> | 88 |
| 5.8.6 | <code>[pre post][ex]</code> <code>hyphenchar</code> | 88 |
| 5.8.7 | <code>hyphenate</code> | 89 |
| 5.8.8 | <code>[set get]</code> <code>hjcode</code> | 89 |



| | | |
|----------|------------------------------------|------------|
| 6 | Font structure | 91 |
| 6.1 | The font tables | 91 |
| 6.2 | Real fonts | 96 |
| 6.3 | Virtual fonts | 98 |
| 6.3.1 | The structure | 98 |
| 6.3.2 | Artificial fonts | 100 |
| 6.3.3 | Example virtual font | 100 |
| 6.4 | The vf library | 101 |
| 6.5 | The font library | 101 |
| 6.5.1 | Loading a TFM file | 101 |
| 6.5.2 | Loading a VF file | 102 |
| 6.5.3 | The fonts array | 102 |
| 6.5.4 | Checking a font's status | 103 |
| 6.5.5 | Defining a font directly | 103 |
| 6.5.6 | Extending a font | 103 |
| 6.5.7 | Projected next font id | 103 |
| 6.5.8 | Font ids | 104 |
| 6.5.9 | Iterating over all fonts | 104 |
| 6.5.10 | \glyphdimensionsmode | 104 |
| 6.5.11 | \discretionaryligaturemode | 105 |
| 6.5.12 | \tracinglostchars | 105 |
| 7 | Math | 107 |
| 7.1 | Traditional alongside OPENTYPE | 107 |
| 7.2 | Unicode math characters | 107 |
| 7.3 | Math styles | 109 |
| 7.3.1 | \mathstyle | 109 |
| 7.3.2 | \Ustack | 110 |
| 7.3.3 | Cramped math styles | 110 |
| 7.4 | Math parameter settings | 112 |
| 7.4.1 | Many new \Umath* primitives | 112 |
| 7.4.2 | Font-based math parameters | 113 |
| 7.5 | Math spacing | 117 |
| 7.5.1 | Inline surrounding space | 117 |
| 7.5.2 | Pairwise spacing | 118 |
| 7.5.3 | Skips around display math | 119 |
| 7.5.4 | Nolimit correction | 119 |
| 7.5.5 | Math italic mess | 120 |
| 7.5.6 | Script and kerning | 120 |
| 7.5.7 | Fixed scripts | 121 |
| 7.5.8 | Penalties: \mathpenaltiesmode | 121 |
| 7.5.9 | Equation spacing: \matheqnogapstep | 122 |
| 7.6 | Math constructs | 122 |
| 7.6.1 | Unscaled fences | 122 |
| 7.6.2 | Accent handling | 123 |
| 7.6.3 | Radical extensions | 124 |
| 7.6.4 | Super- and subscripts | 124 |



| | | |
|----------|--|------------|
| 7.6.5 | Scripts on extensibles | 124 |
| 7.6.6 | Fractions | 126 |
| 7.6.7 | Delimiters: <code>\Uleft</code> , <code>\Umiddle</code> and <code>\Uright</code> | 126 |
| 7.7 | Extracting values | 127 |
| 7.7.1 | Codes | 127 |
| 7.7.2 | Last lines | 127 |
| 7.8 | Math mode | 128 |
| 7.8.1 | Verbose versions of single-character math commands | 128 |
| 7.8.2 | Script commands <code>\Unosuperscript</code> and <code>\Unosubscript</code> | 128 |
| 7.8.3 | Allowed math commands in non-math modes | 129 |
| 7.9 | Goodies | 129 |
| 7.9.1 | Flattening: <code>\mathflattenmode</code> | 129 |
| 7.9.2 | Less Tracing | 129 |
| 7.9.3 | Math options with <code>\mathdefaultsmode</code> | 130 |
| 7.9.4 | Math options with <code>\mathoption</code> | 130 |
| 8 | Nodes | 131 |
| 8.1 | LUA node representation | 131 |
| 8.2 | Main text nodes | 131 |
| 8.2.1 | <code>hlist</code> nodes | 132 |
| 8.2.2 | <code>vlist</code> nodes | 132 |
| 8.2.3 | <code>rule</code> nodes | 132 |
| 8.2.4 | <code>ins</code> nodes | 133 |
| 8.2.5 | <code>mark</code> nodes | 133 |
| 8.2.6 | <code>adjust</code> nodes | 134 |
| 8.2.7 | <code>disc</code> nodes | 134 |
| 8.2.8 | <code>math</code> nodes | 134 |
| 8.2.9 | <code>glue</code> nodes | 135 |
| 8.2.10 | <code>kern</code> nodes | 136 |
| 8.2.11 | <code>penalty</code> nodes | 136 |
| 8.2.12 | <code>glyph</code> nodes | 136 |
| 8.2.13 | <code>boundary</code> nodes | 138 |
| 8.2.14 | <code>local_par</code> nodes | 138 |
| 8.2.15 | <code>dir</code> nodes | 138 |
| 8.2.16 | <code>marginkern</code> nodes | 139 |
| 8.3 | Math noads | 139 |
| 8.3.1 | Math kernel subnodes | 139 |
| 8.3.2 | <code>math_char</code> and <code>math_text_char</code> subnodes | 139 |
| 8.3.3 | <code>sub_box</code> and <code>sub_mlist</code> subnodes | 139 |
| 8.3.4 | <code>delim</code> subnodes | 140 |
| 8.3.5 | Math core nodes | 140 |
| 8.3.6 | simple noad nodes | 141 |
| 8.3.7 | <code>accent</code> nodes | 141 |
| 8.3.8 | <code>style</code> nodes | 141 |
| 8.3.9 | <code>choice</code> nodes | 141 |
| 8.3.10 | <code>radical</code> nodes | 142 |
| 8.3.11 | <code>fraction</code> nodes | 142 |



| | | |
|--------|----------------------------------|-----|
| 8.3.12 | fence nodes | 142 |
| 8.4 | Front-end whatsits | 143 |
| 8.4.1 | open | 143 |
| 8.4.2 | write | 143 |
| 8.4.3 | close | 143 |
| 8.4.4 | user_defined | 143 |
| 8.4.5 | save_pos | 144 |
| 8.4.6 | late_lua | 144 |
| 8.5 | DVI backend whatsits | 144 |
| 8.5.1 | special | 144 |
| 8.6 | PDF backend whatsits | 145 |
| 8.6.1 | pdf_literal and pdf_late_literal | 145 |
| 8.6.2 | pdf_refobj | 145 |
| 8.6.3 | pdf_annot | 145 |
| 8.6.4 | pdf_start_link | 145 |
| 8.6.5 | pdf_end_link | 146 |
| 8.6.6 | pdf_dest | 146 |
| 8.6.7 | pdf_action | 146 |
| 8.6.8 | pdf_thread | 147 |
| 8.6.9 | pdf_start_thread | 147 |
| 8.6.10 | pdf_end_thread | 147 |
| 8.6.11 | pdf_colorstack | 147 |
| 8.6.12 | pdf_setmatrix | 148 |
| 8.6.13 | pdf_save | 148 |
| 8.6.14 | pdf_restore | 148 |
| 8.7 | The node library | 148 |
| 8.7.1 | Introduction | 148 |
| 8.7.2 | is_node | 149 |
| 8.7.3 | types and whatsits | 149 |
| 8.7.4 | id | 149 |
| 8.7.5 | type and subtype | 149 |
| 8.7.6 | fields | 150 |
| 8.7.7 | has_field | 150 |
| 8.7.8 | new | 150 |
| 8.7.9 | free, flush_node and flush_list | 150 |
| 8.7.10 | copy and copy_list | 151 |
| 8.7.11 | prev and next | 151 |
| 8.7.12 | current_attr | 151 |
| 8.7.13 | hpack | 152 |
| 8.7.14 | vpack | 152 |
| 8.7.15 | prepend_prevdepth | 153 |
| 8.7.16 | dimensions and rangedimensions | 153 |
| 8.7.17 | mlist_to_hlist | 154 |
| 8.7.18 | slide | 154 |
| 8.7.19 | tail | 154 |
| 8.7.20 | length and type count | 155 |



| | | |
|----------|--|------------|
| 8.7.21 | is_char and is_glyph | 155 |
| 8.7.22 | traverse | 155 |
| 8.7.23 | traverse_id | 156 |
| 8.7.24 | traverse_char and traverse_glyph | 156 |
| 8.7.25 | traverse_list | 157 |
| 8.7.26 | has_glyph | 157 |
| 8.7.27 | end_of_math | 157 |
| 8.7.28 | remove | 157 |
| 8.7.29 | insert_before | 157 |
| 8.7.30 | insert_after | 158 |
| 8.7.31 | first_glyph | 158 |
| 8.7.32 | ligaturing | 158 |
| 8.7.33 | kerning | 158 |
| 8.7.34 | unprotect_glyph[s] | 159 |
| 8.7.35 | protect_glyph[s] | 159 |
| 8.7.36 | last_node | 159 |
| 8.7.37 | write | 159 |
| 8.7.38 | protrusion_skippable | 159 |
| 8.8 | Glue handling | 159 |
| 8.8.1 | setglue | 159 |
| 8.8.2 | getglue | 160 |
| 8.8.3 | is_zero_glue | 160 |
| 8.9 | Attribute handling | 160 |
| 8.9.1 | Attributes | 160 |
| 8.9.2 | attribute_list nodes | 160 |
| 8.9.3 | attr nodes | 161 |
| 8.9.4 | has_attribute | 161 |
| 8.9.5 | get_attribute | 161 |
| 8.9.6 | find_attribute | 161 |
| 8.9.7 | set_attribute | 161 |
| 8.9.8 | unset_attribute | 162 |
| 8.9.9 | slide | 162 |
| 8.9.10 | check_discretionary, check_discretionaries | 162 |
| 8.9.11 | flatten_discretionaries | 162 |
| 8.9.12 | family_font | 162 |
| 8.10 | Two access models | 163 |
| 8.11 | Properties | 168 |
| 9 | LUA callbacks | 173 |
| 9.1 | Registering callbacks | 173 |
| 9.2 | File discovery callbacks | 173 |
| 9.2.1 | find_read_file and find_write_file | 174 |
| 9.2.2 | find_font_file | 174 |
| 9.2.3 | find_output_file | 174 |
| 9.2.4 | find_format_file | 174 |
| 9.2.5 | find_vf_file | 175 |
| 9.2.6 | find_map_file | 175 |



| | | |
|--------|--|-----|
| 9.2.7 | find_enc_file | 175 |
| 9.2.8 | find_pk_file | 175 |
| 9.2.9 | find_data_file | 175 |
| 9.2.10 | find_opentype_file | 175 |
| 9.2.11 | find_truetype_file and find_type1_file | 175 |
| 9.2.12 | find_image_file | 176 |
| 9.3 | File reading callbacks | 176 |
| 9.3.1 | open_read_file | 176 |
| 9.3.2 | General file readers | 177 |
| 9.4 | Data processing callbacks | 178 |
| 9.4.1 | process_input_buffer | 178 |
| 9.4.2 | process_output_buffer | 178 |
| 9.4.3 | process_jobname | 178 |
| 9.5 | Node list processing callbacks | 178 |
| 9.5.1 | contribute_filter | 178 |
| 9.5.2 | buildpage_filter | 179 |
| 9.5.3 | build_page_insert | 179 |
| 9.5.4 | pre_linebreak_filter | 180 |
| 9.5.5 | linebreak_filter | 181 |
| 9.5.6 | append_to_vlist_filter | 181 |
| 9.5.7 | post_linebreak_filter | 181 |
| 9.5.8 | hpack_filter | 181 |
| 9.5.9 | vpack_filter | 182 |
| 9.5.10 | hpack_quality | 182 |
| 9.5.11 | vpack_quality | 182 |
| 9.5.12 | process_rule | 183 |
| 9.5.13 | pre_output_filter | 183 |
| 9.5.14 | hyphenate | 183 |
| 9.5.15 | ligaturing | 183 |
| 9.5.16 | kerning | 184 |
| 9.5.17 | insert_local_par | 184 |
| 9.5.18 | mlist_to_hlist | 184 |
| 9.6 | Information reporting callbacks | 184 |
| 9.6.1 | pre_dump | 184 |
| 9.6.2 | start_run | 185 |
| 9.6.3 | stop_run | 185 |
| 9.6.4 | start_page_number | 185 |
| 9.6.5 | stop_page_number | 185 |
| 9.6.6 | show_error_hook | 185 |
| 9.6.7 | show_error_message | 186 |
| 9.6.8 | show_ignored_error_message | 186 |
| 9.6.9 | show_lua_error_hook | 186 |
| 9.6.10 | start_file | 186 |
| 9.6.11 | stop_file | 186 |
| 9.6.12 | call_edit | 187 |
| 9.6.13 | finish_synctex | 187 |



| | | |
|-----------|---|------------|
| 9.6.14 | wrapup_run | 187 |
| 9.7 | PDF related callbacks | 187 |
| 9.7.1 | finish_pdffile | 187 |
| 9.7.2 | finish_pdfpage | 187 |
| 9.7.3 | page_order_index | 187 |
| 9.7.4 | process_pdf_image_content | 188 |
| 9.8 | Font-related callbacks | 188 |
| 9.8.1 | define_font | 188 |
| 9.8.2 | glyph_not_found and glyph_info | 189 |
| 9.8.3 | provide_charproc_data | 189 |
| 10 | The T_EX related libraries | 191 |
| 10.1 | The lua library | 191 |
| 10.1.1 | Version information | 191 |
| 10.1.2 | Bytecode registers | 191 |
| 10.1.3 | Chunk name registers | 191 |
| 10.1.4 | Introspection | 192 |
| 10.2 | The status library | 192 |
| 10.3 | The tex library | 194 |
| 10.3.1 | Introduction | 194 |
| 10.3.2 | Internal parameter values, set and get | 194 |
| 10.3.3 | Convert commands | 197 |
| 10.3.4 | Last item commands | 198 |
| 10.3.5 | Accessing registers: set*, get* and is* | 198 |
| 10.3.6 | Character code registers: [get set]*code[s] | 200 |
| 10.3.7 | Box registers: [get set]box | 201 |
| 10.3.8 | Reusing boxes: [use save]boxresource and getboxresourcedimensions | 202 |
| 10.3.9 | triggerbuildpage | 202 |
| 10.3.10 | splitbox | 202 |
| 10.3.11 | Accessing math parameters: [get set]math | 203 |
| 10.3.12 | Special list heads: [get set]list | 204 |
| 10.3.13 | Semantic nest levels: getnest and ptr | 204 |
| 10.3.14 | Print functions | 205 |
| 10.3.15 | Helper functions | 207 |
| 10.3.16 | Functions for dealing with primitives | 210 |
| 10.3.17 | Core functionality interfaces | 214 |
| 10.3.18 | Randomizers | 216 |
| 10.3.19 | Functions related to syntex | 216 |
| 10.4 | The texconfig table | 217 |
| 10.5 | The texio library | 219 |
| 10.5.1 | write | 219 |
| 10.5.2 | write_nl | 219 |
| 10.5.3 | setescape | 219 |
| 10.5.4 | closeinput | 219 |



| | | |
|-----------|---|------------|
| 10.6 | The token library | 219 |
| 10.6.1 | The scanner | 219 |
| 10.6.2 | Picking up one token | 222 |
| 10.6.3 | Creating tokens | 222 |
| 10.6.4 | Macros | 223 |
| 10.6.5 | Pushing back | 224 |
| 10.6.6 | Nota bene | 224 |
| 10.7 | The kpse library | 226 |
| 10.7.1 | set_program_name and new | 226 |
| 10.7.2 | record_input_file and record_output_file | 226 |
| 10.7.3 | find_file | 227 |
| 10.7.4 | lookup | 227 |
| 10.7.5 | init_prog | 228 |
| 10.7.6 | readable_file | 228 |
| 10.7.7 | expand_path | 228 |
| 10.7.8 | expand_var | 228 |
| 10.7.9 | expand_braces | 229 |
| 10.7.10 | in_name_ok | 229 |
| 10.7.11 | in_name_ok_silent_extended | 229 |
| 10.7.12 | out_name_ok | 229 |
| 10.7.13 | out_name_ok_silent_extended | 229 |
| 10.7.14 | show_path | 229 |
| 10.7.15 | var_value | 229 |
| 10.7.16 | version | 230 |
| 10.7.17 | check_permission | 230 |
| 11 | The graphic libraries | 231 |
| 11.1 | The img library | 231 |
| 11.1.1 | new | 231 |
| 11.1.2 | fields | 232 |
| 11.1.3 | scan | 233 |
| 11.1.4 | copy | 234 |
| 11.1.5 | write, immediatewrite, immediatewriteobject | 234 |
| 11.1.6 | node | 235 |
| 11.1.7 | types | 235 |
| 11.1.8 | boxes | 235 |
| 11.2 | The mplib library | 236 |
| 11.2.1 | new | 236 |
| 11.2.2 | statistics | 237 |
| 11.2.3 | execute | 237 |
| 11.2.4 | finish | 237 |
| 11.2.5 | Result table | 238 |
| 11.2.6 | Subsidiary table formats | 240 |
| 11.2.7 | Pens and pen_info | 241 |
| 11.2.8 | Character size information | 242 |



| | | |
|-----------|---|------------|
| 12 | The fontloader | 243 |
| 12.1 | Getting quick information on a font | 243 |
| 12.2 | Loading an OPENTYPE or TRUETYPE file | 243 |
| 12.3 | Applying a 'feature file' | 245 |
| 12.4 | Applying an 'AFM file' | 245 |
| 12.5 | Fontloader font tables | 245 |
| 12.6 | Table types | 246 |
| 12.6.1 | The main table | 246 |
| 12.6.2 | glyphs | 248 |
| 12.6.3 | map | 251 |
| 12.6.4 | private | 252 |
| 12.6.5 | cidinfo | 252 |
| 12.6.6 | pfminfo | 252 |
| 12.6.7 | names | 253 |
| 12.6.8 | anchor_classes | 254 |
| 12.6.9 | gpos | 254 |
| 12.6.10 | gsub | 255 |
| 12.6.11 | ttf_tables and ttf_tab_saved | 255 |
| 12.6.12 | mm | 255 |
| 12.6.13 | mark_classes | 256 |
| 12.6.14 | math | 256 |
| 12.6.15 | validation_state | 257 |
| 12.6.16 | horiz_base and vert_base | 257 |
| 12.6.17 | altuni | 257 |
| 12.6.18 | vert_variants and horiz_variants | 257 |
| 12.6.19 | mathkern | 258 |
| 12.6.20 | kerns | 258 |
| 12.6.21 | vkerns | 258 |
| 12.6.22 | texdata | 258 |
| 12.6.23 | lookups | 258 |
| 13 | The HarfBuzz libraries | 261 |
| 13.1 | The luaharfbuzz library | 261 |
| 13.1.1 | Example | 279 |
| 14 | The backend libraries | 285 |
| 14.1 | The pdf library | 285 |
| 14.1.1 | mapfile, mapline | 285 |
| 14.1.2 | [set get][catalog info names trailer] | 285 |
| 14.1.3 | [set get][pageattributes pageresources pagesattributes] | 285 |
| 14.1.4 | [set get][xformattributes xformresources] | 285 |
| 14.1.5 | [set get][major minor]version | 285 |
| 14.1.6 | getcreationdate | 286 |
| 14.1.7 | [set get]inclusionerrorlevel and [set get]ignoreunknownimages | 286 |
| 14.1.8 | [set get]suppressoptionalinfo, [set get]trailerid, [set get]omitcidset, [set get]omitinfo, [set get]omitmedia- box, [set get]omitprocset, [set get]ptexprefix | 286 |



| | | |
|---------|---|------------|
| 14.1.9 | [set get][obj]compresslevel and [set get]recompress | 286 |
| 14.1.10 | [set get]gentounicode | 286 |
| 14.1.11 | [set get]decimaldigits | 287 |
| 14.1.12 | [set get]pkresolution | 287 |
| 14.1.13 | getlast[obj link annot] and getretval | 287 |
| 14.1.14 | getmaxobjnum and getobjtype, getfontname, getfontobjnum, getfontsize, getxformname | 287 |
| 14.1.15 | [set get]origin | 287 |
| 14.1.16 | [set get]imageresolution | 287 |
| 14.1.17 | [set get][link dest thread xform]margin | 287 |
| 14.1.18 | get[pos hpos vpos] | 287 |
| 14.1.19 | [has get]matrix | 288 |
| 14.1.20 | print | 288 |
| 14.1.21 | immediateobj | 288 |
| 14.1.22 | obj | 289 |
| 14.1.23 | refobj | 290 |
| 14.1.24 | reserveobj | 290 |
| 14.1.25 | getpageref | 290 |
| 14.1.26 | registerannot | 290 |
| 14.1.27 | newcolorstack | 291 |
| 14.1.28 | setfontattributes | 291 |
| 14.2 | The pdfengine library | 291 |
| 14.2.1 | Introduction | 291 |
| 14.2.2 | open, new, getstatus, close, unencrypt | 291 |
| 14.2.3 | getsize, getversion, getnofobjects, getnofpages, getmemoryusage | 292 |
| 14.2.4 | get[catalog trailer info] | 292 |
| 14.2.5 | getpage, getbox | 292 |
| 14.2.6 | get[string integer number boolean name], type | 293 |
| 14.2.7 | get[from][dictionary array stream] | 293 |
| 14.2.8 | [open close readfrom whole]stream | 294 |
| 14.2.9 | getfrom[dictionary array] | 294 |
| 14.2.10 | [dictionary array]totable | 294 |
| 14.2.11 | getfromreference | 295 |
| 14.3 | Memory streams | 295 |
| 14.4 | The pdfscanner library | 295 |
| | Topics | 299 |
| | Primitives | 303 |
| | Callbacks | 311 |
| | Nodes | 313 |



Libraries

315

Statistics

323





Introduction

This is the reference manual of Lua \TeX . We don't claim it is complete and we assume that the reader knows about \TeX as described in "The \TeX Book", the " ϵ - \TeX manual", the "pdf \TeX manual", etc. Additional reference material is published in journals of user groups and Con \TeX t related documentation.

It took about a decade to reach stable version 1.0, but for good reason. Successive versions brought new functionality, more control, some cleanup of internals. Experimental features evolved into stable ones or were dropped. Already quite early Lua \TeX could be used for production and it was used on a daily basis by the authors. Successive versions sometimes demanded an adaption to the Lua interfacing, but the concepts were unchanged. The current version can be considered stable in functionality and there will be no fundamental changes. Of course we then can decide to move towards version 2.00 with different properties.

Don't expect Lua \TeX to behave the same as pdf \TeX ! Although the core functionality of that 8 bit engine was starting point, it has been combined with the directional support of Omega (Aleph). But, Lua \TeX can behave different due to its wide (32 bit) characters, many registers and large memory support. The pdf code produced differs from pdf \TeX but users will normally not notice that. There is native utf input, support for large (more than 8 bit) fonts, and the math machinery is tuned for OpenType math. There is support for directional typesetting too. The log output can differ from other engines and will likely differ more as we move forward. When you run plain \TeX for sure Lua \TeX runs slower than pdf \TeX but when you run for instance Con \TeX t MkIV in many cases it runs faster, especially when you have a bit more complex documents or input. Anyway, 32 bit all-over combined with more features has a price, but on a modern machine this is no real problem.

Testing is done with Con \TeX t, but Lua \TeX should work fine with other macro packages too. For that purpose we provide generic font handlers that are mostly the same as used in Con \TeX t. Discussing specific implementations is beyond this manual. Even when we keep Lua \TeX lean and mean, we already have enough to discuss here.

Lua \TeX consists of a number of interrelated but (still) distinguishable parts. The organization of the source code is adapted so that it can glue all these components together. We continue cleaning up side effects of the accumulated code in \TeX engines (especially code that is not needed any longer).

- ▶ We started out with most of pdf \TeX version 1.40.9. The code base was converted to C and split in modules. Experimental features were removed and utility macros are not inherited because their functionality can be programmed in Lua. The number of backend interface commands has been reduced to a few. The so called extensions are separated from the core (which we try to keep close to the original \TeX core). Some mechanisms like expansion and protrusion can behave different from the original due to some cleanup and optimization. Some whatsit based functionality (image support and reusable content) is now core functionality. We don't stay in sync with pdf \TeX development.
- ▶ The direction model from Aleph RC4 (which is derived from Omega) is included. The related primitives are part of core Lua \TeX but at the node level directional support is no longer based



on so called whatsits but on real nodes with relevant properties. The number of directions is limited to the useful set and the backend has been made direction aware.

- ▶ Neither Aleph's I/O translation processes, nor tcx files, nor `encTEX` are available. These encoding-related functions are superseded by a Lua-based solution (reader callbacks). In a similar fashion all file io can be intercepted.
- ▶ We currently use Lua 5.3.*. There are few Lua libraries that we consider part of the core Lua machinery, for instance `lpeg`. There are additional Lua libraries that interface to the internals of T_EX. We also keep the Lua 5.2 `bit32` library around.
- ▶ There are various T_EX extensions but only those that cannot be done using the Lua interfaces. The math machinery often has two code paths: one traditional and the other more suitable for wide OpenType fonts. Here we follow the Microsoft specifications as much as possible. Some math functionality has been opened up a bit so that users have more control.
- ▶ The fontloader uses parts of FontForge 2008.11.17 combined with additional code specific for usage in a T_EX engine. We try to minimize specific font support to what T_EX needs: character references and dimensions and delegate everything else to Lua. That way we keep T_EX open for extensions without touching the core. In order to minimize dependencies at some point we may decide to make this an optional library.
- ▶ The MetaPost library is integral part of LuaT_EX. This gives T_EX some graphical capabilities using a relative high speed graphical subsystem. Again Lua is used as glue between the frontend and backend. Further development of MetaPost is closely related to LuaT_EX.
- ▶ The virtual font technology that comes with T_EX has been integrated into the font machinery in a way that permits creating virtual fonts at runtime. Because LuaT_EX can also act as a Lua interpreter this means that a complete T_EX workflow can be built without the need for additional programs.
- ▶ The versions starting from 1.09 no longer use the poppler library for inclusion but a light-weight dedicated one. This removes a dependency but also makes the inclusion code of LuaT_EX different from pdfT_EX. In fact it was already much different due to the Lua image interfacing.

We try to keep upcoming versions compatible but intermediate releases can contain experimental features. A general rule is that versions that end up on T_EXLive and/or are released around ConT_EXt meetings are stable. Any version between the yearly T_EXLive releases are to be considered beta and in the repository end up as trunk releases. We have an experimental branch that we use for development but there is no support for any of its experimental features. Intermediate releases (from trunk) are normally available via the ConT_EXt distribution channels (the garden and so called minimal).

Version 1.10 is more or less an endpoint in development: this is what you get. Because not only ConT_EXt, that we can adapt rather easily, uses LuaT_EX, we cannot change fundamentals without unforeseen consequences. By now it has been proven that Lua can be used to extend the core functionality so there is no need to add more, and definitely no hard coded solutions for (not so) common problems. Of course there will be bug fixes, maybe some optimization, and there might



even be some additions or non-intrusive improvements, but only after testing outside the stable release. After all, the binary is already more than large enough and there is not that much to gain.

You might find Lua helpers that are not yet documented. These are considered experimental, although when you encounter them in a ConT_EXt version that has been around for a while you can assume that they will stay. Of course it can just be that we forgot to document them yet.

A manual like this is not really meant as tutorial, for that we refer to documents that ship with ConT_EXt, articles, etc. It is also never complete enough for all readers. We try to keep up but the reader needs to realize that it's all volunteer work done in spare time. And for sure, complaining about a bad manual or crappy documentation will not really motivate us to spend more time on it. That being said, we hope that this document is useful.

Hans Hagen
Harmut Henkel
Taco Hoekwater
Luigi Scarso

Version : February 10, 2025
LuaT_EX : luatex 1.21 / 7662
ConT_EXt : MkIV 2024.02.27 09:18





1 Preamble

This is a reference manual, not a tutorial. This means that we discuss changes relative to traditional T_EX and also present new functionality. As a consequence we will refer to concepts that we assume to be known or that might be explained later.

The average user doesn't need to know much about what is in this manual. For instance fonts and languages are normally dealt with in the macro package that you use. Messing around with node lists is also often not really needed at the user level. If you do mess around, you'd better know what you're dealing with. Reading "The T_EX Book" by Donald Knuth is a good investment of time then also because it's good to know where it all started. A more summarizing overview is given by "T_EX by Topic" by Victor Eijkhout. You might want to peek in "The ϵ -T_EX manual" and documentation about pdfT_EX.

But . . . if you're here because of Lua, then all you need to know is that you can call it from within a run. The macro package that you use probably will provide a few wrapper mechanisms but the basic `\directlua` command that does the job is:

```
\directlua{tex.print("Hi there")}
```

You can put code between curly braces but if it's a lot you can also put it in a file and load that file with the usual Lua commands.

If you still decide to read on, then it's good to know what nodes are, so we do a quick introduction here. If you input this text:

```
Hi There
```

eventually we will get a linked lists of nodes, which in ascii art looks like:

```
H <=> i <=> [glue] <=> T <=> h <=> e <=> r <=> e
```

When we have a paragraph, we actually get something:

```
[localpar] <=> H <=> i <=> [glue] <=> T <=> h <=> e <=> r <=> e <=> [glue]
```

Each character becomes a so called glyph node, a record with properties like the current font, the character code and the current language. Spaces become glue nodes. There are many node types that we will discuss later. Each node points back to a previous node or next node, given that these exist.

It's also good to know beforehand that T_EX is basically centered around creating paragraphs and pages. The par builder takes a list and breaks it into lines. We turn horizontal material into vertical. Lines are so called boxes and can be separated by glue, penalties and more. The page builder accumulates lines and when feasible triggers an output routine that will take the list so far. Constructing the actual page is not part of T_EX but done using primitives that permit manipulation of boxes. The result is handled back to T_EX and flushed to a (often pdf) file.

The LuaT_EX engine provides hooks for Lua code at nearly every reasonable point in the process: collecting content, hyphenating, applying font features, breaking into lines, etc. This means



that you can overload T_EX's natural behaviour, which still is the benchmark. When we refer to 'callbacks' we means these hooks.

Where plain T_EX is basically a basic framework for writing a specific style, macro packages like ConT_EXt and L^AT_EX provide the user a whole lot of additional tools to make documents look good. They hide the dirty details of font management, language demands, turning structure into typeset results, wrapping pages, including images, and so on. You should be aware of the fact that when you hook in your own code to manipulate lists, this can interfere with the macro package that you use.

When you read about nodes in the following chapters it's good to keep in mind their commands that relate to them. Here are a few:

| COMMAND | NODE | EXPLANATION |
|-------------------------------|-------|--|
| <code>\hbox</code> | hlist | horizontal box |
| <code>\vbox</code> | vlist | vertical box with the baseline at the bottom |
| <code>\vtop</code> | vlist | vertical box with the baseline at the top |
| <code>\hskip</code> | glue | horizontal skip with optional stretch and shrink |
| <code>\vskip</code> | glue | vertical skip with optional stretch and shrink |
| <code>\kern</code> | kern | horizontal or vertical fixed skip |
| <code>\discretionary</code> | disc | hyphenation point (pre, post, replace) |
| <code>\char</code> | glyph | a character |
| <code>\hrule</code> | rule | a horizontal rule |
| <code>\vrule</code> | rule | a vertical rule |
| <code>\textdir(ection)</code> | dir | a change in text direction |

For now this should be enough to enable you to understand the next chapters.



2 Basic T_EX enhancements

2.1 Introduction

2.1.1 Primitive behaviour

From day one, LuaT_EX has offered extra features compared to the superset of pdfT_EX, which includes ϵ -T_EX, and Aleph. This has not been limited to the possibility to execute Lua code via `\directlua`, but LuaT_EX also adds functionality via new T_EX-side primitives or extensions to existing ones.

When LuaT_EX starts up in ‘iniluatex’ mode (`luatex -ini`), it defines only the primitive commands known by T_EX82 and the one extra command `\directlua`. As is fitting, a Lua function has to be called to add the extra primitives to the user environment. The simplest method to get access to all of the new primitive commands is by adding this line to the format generation file:

```
\directlua { tex.enableprimitives('',tex.extraprimitives()) }
```

But be aware that the curly braces may not have the proper `\catcode` assigned to them at this early time (giving a ‘Missing number’ error), so it may be needed to put these assignments before the above line:

```
\catcode `{=1  
\catcode `}=2
```

More fine-grained primitives control is possible and you can look up the details in section 10.3.16. For simplicity’s sake, this manual assumes that you have executed the `\directlua` command as given above.

The startup behaviour documented above is considered stable in the sense that there will not be backward-incompatible changes any more. We have promoted some rather generic pdfT_EX primitives to core LuaT_EX ones, and the few that we inherited from Aleph (Omega) are also promoted. Effectively this means that we now only have the `tex`, `etex` and `luatex` sets left.

In Chapter 3 we discuss several primitives that are derived from pdfT_EX and Aleph (Omega). Here we stick to real new ones. In the chapters on fonts and math we discuss a few more new ones.

2.1.2 Version information

2.1.2.1 `\luatexbanner`, `\luatexversion` and `\luatexrevision`

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

| PRIMITIVE | VALUE | EXPLANATION |
|----------------------------|--------------------------------|---|
| <code>\luatexbanner</code> | This is LuaTeX, Version 1.21.0 | the banner reported on the command line |



| | | |
|------------------------------|-----|---|
| <code>\luatexversion</code> | 121 | a combination of major and minor number |
| <code>\luatexrevision</code> | 0 | the revision number, the current value is |

The official LuaT_EX version is defined as follows:

- ▶ The major version is the integer result of `\luatexversion` divided by 100. The primitive is an ‘internal variable’, so you may need to prefix its use with `\the` depending on the context.
- ▶ The minor version is the two-digit result of `\luatexversion` modulo 100.
- ▶ The revision is reported by `\luatexrevision`. This primitive expands to a positive integer.
- ▶ The full version number consists of the major version, minor version and revision, separated by dots.

2.1.2.2 `\formatname`

The `\formatname` 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. You can use this token list to provide your own version info.

2.2 UNICODE text support

2.2.1 Extended ranges

Text input and output is now considered to be Unicode text, so input characters can use the full range of Unicode ($2^{20} + 2^{16} - 1 = 0x10FFFF$). Later chapters will talk of characters and glyphs. Although these are not 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 LuaT_EX there is no clear separation between the two concepts. Because the subtype of a glyph node can be changed in Lua it is up to the user. Subtypes larger than 255 indicate that font processing has happened.

A few primitives are affected by this, all in a similar fashion: each of them has to accommodate for a larger range of acceptable numbers. For instance, `\char` now accepts values between 0 and 1,114,111. 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 T_EX-based engines. The affected commands with an altered initial (left of the equal sign) or secondary (right of the equal sign) value are: `\char`, `\lccode`, `\uccode`, `\hjcode`, `\catcode`, `\sfcode`, `\efcode`, `\lpcode`, `\rprcode`, `\chardef`.

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 section 9.3. Normalization of the Unicode input is on purpose not built-in and can be handled by a macro package during callback processing. We have made some practical choices and the user has to live with those.

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 time comes to print a character $c \geq 1,114,112$, LuaT_EX will actually print the single byte corresponding to c minus 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. You can disable escaping with `texio.setescape(false)` in which case you get the normal characters on the console.

2.2.2 `\Uchar`

The expandable command `\Uchar` reads a number between 0 and 1,114,111 and expands to the associated Unicode character.

2.2.3 Extended tables

All traditional \TeX and ε - \TeX registers can be 16-bit numbers. The affected commands are:

| | | | |
|----------------------|-------------------------|-----------------------|----------------------|
| <code>\count</code> | <code>\countdef</code> | <code>\box</code> | <code>\wd</code> |
| <code>\dimen</code> | <code>\dimendef</code> | <code>\unhbox</code> | <code>\ht</code> |
| <code>\skip</code> | <code>\skipdef</code> | <code>\unvbox</code> | <code>\dp</code> |
| <code>\muskip</code> | <code>\muskipdef</code> | <code>\copy</code> | <code>\setbox</code> |
| <code>\marks</code> | <code>\toksdef</code> | <code>\unhcopy</code> | <code>\vsplit</code> |
| <code>\toks</code> | <code>\insert</code> | <code>\unvcopy</code> | |

Because font memory management has been rewritten, character properties in fonts are no longer shared among font instances that originate from the same metric file. Of course we share fonts in the backend when possible so that the resulting pdf file is as efficient as possible, but for instance also expansion and protrusion no longer use copies as in pdf \TeX .

2.3 Attributes

2.3.1 Nodes

When \TeX reads input it will interpret the stream according to the properties of the characters. Some signal a macro name and trigger expansion, others open and close groups, trigger math mode, etc. What’s left over becomes the typeset text. Internally we get linked list of nodes. Characters become glyph nodes that have for instance a font and char property and `\kern 10pt` becomes a kern node with a width property. Spaces are alien to \TeX as they are turned into glue nodes. So, a simple paragraph is mostly a mix of sequences of glyph nodes (words) and glue nodes (spaces).

The sequences of characters at some point are extended with disc nodes that relate to hyphenation. After that font logic can be applied and we get a list where some characters can be replaced, for instance multiple characters can become one ligature, and font kerns can be injected. This is driven by the font properties.

Boxes (like `\hbox` and `\vbox`) become `hlist` or `vlist` nodes with width, height, depth and shift properties and a pointer `list` to its actual content. Boxes can be constructed explicitly or can



be the result of subprocesses. For instance, when lines are broken into paragraphs, the lines are a linked list of `hlist` nodes.

So, to summarize: all that you enter as content eventually becomes a node, often as part of a (nested) list structure. They have a relative small memory footprint and carry only the minimal amount of information needed. In traditional \TeX a character node only held the font and slot number, in $\text{Lua}\TeX$ we also store some language related information, the expansion factor, etc. Now that we have access to these nodes from Lua it makes sense to be able to carry more information with an node and this is where attributes kick in.

2.3.2 Attribute registers

Attributes are a completely new concept in $\text{Lua}\TeX$. 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> <32-bit number>  
\attributedef <cname> <optional equals> <16-bit number>
```

Conceptually, an attribute is either 'set' or 'unset'. Unset attributes have a special negative value to indicate that they are unset, that value is the lowest legal value: `-"7FFFFFFF` in hexadecimal, a.k.a. `-2147483647` in decimal. It follows that the value `-"7FFFFFFF` cannot be used as a legal attribute value, but you *can* assign `-"7FFFFFFF` to 'unset' an attribute. All attributes start out in this '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. Further information about how to use attributes for node list processing from Lua is given in chapter 8.

Attributes are stored in a sorted (sparse) linked list that are shared when possible. This permits efficient testing and updating. You can define many thousands of attributes but normally such a large number makes no sense and is also not that efficient because each node carries a (possibly shared) link to a list of currently set attributes. But they are a convenient extension and one of the first extensions we implemented in $\text{Lua}\TeX$.

2.3.3 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 $\text{Lua}\TeX$ regularly. A few of the more obvious problematic cases are dealt with: the attributes for nodes that are created during hyphenation, kerning and ligaturing borrow their attributes from their surrounding glyphs, and it is possible to influence box attributes directly.

When you assemble a box in a register, the attributes of the nodes contained in the box are unchanged when such a box is placed, unboxed, or copied. In this respect attributes act the



same as characters that have been converted to references to glyphs in fonts. For instance, when you use attributes to implement color support, each node carries information about its eventual color. In that case, unless you implement mechanisms that deal with it, applying a color to already boxed material will have no effect. Keep in mind that this incompatibility is mostly due to the fact that separate specials and literals are a more unnatural approach to colors than attributes.

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

```
\attribute997=123
\attribute998=456
\setbox0=\hbox {Hello}
\setbox2=\hbox attr 999 = 789 attr 998 = -"7FFFFFFF{Hello}
```

Box 0 now has attributes 997 and 998 set while box 2 has attributes 997 and 999 set while the nodes inside that box will all have attributes 997 and 998 set. Assigning the maximum negative value causes an attribute to be ignored.

To give you an idea of what this means at the Lua end, take the following code:

```
for b=0,2,2 do
  for a=997, 999 do
    tex.sprint("box ", b, " : attr ",a," : ",tostring(tex.box[b] [a]))
    tex.sprint("\quad\quad")
    tex.sprint("list ",b, " : attr ",a," : ",tostring(tex.box[b].list[a]))
    tex.sprint("\par")
  end
end
```

Later we will see that you can access properties of a node. The boxes here are so called `hlist` nodes that have a field `list` that points to the content. Because the attributes are a list themselves you can access them by indexing the node (here we do that with `[a]`). Running this snippet gives:

```
box 0 : attr 997 : 123   list 0 : attr 997 : 123
box 0 : attr 998 : 456   list 0 : attr 998 : 456
box 0 : attr 999 : nil   list 0 : attr 999 : nil
box 2 : attr 997 : 123   list 2 : attr 997 : 123
box 2 : attr 998 : nil   list 2 : attr 998 : 456
box 2 : attr 999 : 789   list 2 : attr 999 : nil
```

Because some values are not set we need to apply the `tostring` function here so that we get the word `nil`.

2.4 LUA related primitives

2.4.1 `\directlua`

In order to merge Lua code with \TeX input, a few new primitives are needed. The primitive



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

```
\directlua <general text>
\directlua <16-bit number> <general text>
```

The `<general text>` is expanded fully, and then fed into the Lua interpreter. 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. In such a chunk you can use the `local` directive to keep your variables from interfering with those used by the macro package.

The conversion to and from 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’ the first line comment will run on until the end of the input. You will either need to use T_EX-style line comments (starting with `%`), or change the T_EX category codes locally. Another possibility is to say:

```
\begingroup
\endlinechar=10
\directlua ...
\endgroup
```

Then Lua line comments can be used, since T_EX does not replace line endings with spaces. Of course such an approach depends on the macro package that you use.

The `<16-bit number>` designates a name of a Lua chunk and is taken from the `lua.name` array (see the documentation of the `lua` table further in this manual). When a chunk name starts with a `@` it will be displayed as a file name. This is a side effect of the way Lua implements error handling.

The `\directlua` command is expandable. Since it passes Lua code to the Lua interpreter its expansion from the T_EX viewpoint is usually empty. However, there are some Lua functions that produce material to be read by T_EX, the so called print functions. The most simple use of these is `tex.print(<string> s)`. The characters of the string `s` will be placed on the T_EX input buffer, that is, ‘before T_EX’s eyes’ to be read by T_EX immediately. For example:

```
\count10=20
a\directlua{tex.print(tex.count[10]+5)}b
```

expands to

```
a25b
```

Here is another example:

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

will result in

```
 $\pi = 3.1415926535898$ 
```

Note that the expansion of `\directlua` is a sequence of characters, not of tokens, contrary to all T_EX commands. So formally speaking its expansion is null, but it places material on a pseudo-file to be immediately read by T_EX, as ε -T_EX’s `\scantokens`. For a description of print functions look at section 10.3.14.



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. Often, 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 Lua_{TeX} 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.

2.4.2 `\latelua` and `\lateluafunction`

Contrary to `\directlua`, `\latelua` stores Lua code in a whatsit that will be processed at the time of shipping out. Its intended use is a cross between pdf literals (often available as `\pdfliteral`) and the traditional _{TeX} extension `\write`. Within the Lua code you can print pdf statements directly to the pdf file via `pdf.print`, or you can write to other output streams via `texio.write` or simply using Lua io routines.

```
\latelua <general text>
\latelua <16-bit number> <general text>
```

Expansion of macros in the final `<general text>` is delayed until just before the whatsit is executed (like in `\write`). With regard to pdf output stream `\latelua` behaves as pdf page literals. The name `<general text>` and `<16-bit number>` behave in the same way as they do for `\directlua`.

The `\lateluafunction` primitive takes a number and is similar to `\luafunction` but gets delayed to shipout time. It's just there for completeness.

2.4.3 `\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` respectively. 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 _{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`:

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

2.4.4 `\luafunction`, `\luafunctioncall` and `\luaodef`

The `\directlua` commands involves tokenization of its argument (after picking up an optional name or number specification). The tokenlist is then converted into a string and given to Lua to turn into a function that is called. The overhead is rather small but when you have millions of calls it can have some impact. For this reason there is a variant call available: `\luafunction`. This command is used as follows:



```

\directlua {
  local t = lua.get_functions_table()
  t[1] = function() tex.print("!") end
  t[2] = function() tex.print("?") end
}

```

```

\luafunction1
\luafunction2

```

Of course the functions can also be defined in a separate file. There is no limit on the number of functions apart from normal Lua limitations. Of course there is the limitation of no arguments but that would involve parsing and thereby give no gain. The function, when called in fact gets one argument, being the index, so in the following example the number 8 gets typeset.

```

\directlua {
  local t = lua.get_functions_table()
  t[8] = function(slot) tex.print(slot) end
}

```

The `\luafunctioncall` primitive does the same but is unexpandable, for instance in an `\edef`. In addition LuaTeX provides a definer:

```

          \luadef\MyFunctionA 1
    \global\luadef\MyFunctionB 2
\protected\global\luadef\MyFunctionC 3

```

You should really use these commands with care. Some references get stored in tokens and assume that the function is available when that token expands. On the other hand, as we have tested this functionality in relative complex situations normal usage should not give problems.

2.4.5 `\luabytecode` and `\luabytecodecall`

Analogue to the function callers discussed in the previous section we have byte code callers. Again the call variant is unexpandable.

```

\directlua {
  lua.bytecode[9998] = function(s)
    tex.sprint(s*token.scan_int())
  end
  lua.bytecode[5555] = function(s)
    tex.sprint(s*token.scan_dimen())
  end
}

```

This works with:

```

\luabytecode 9998 5 \luabytecode 5555 5sp
\luabytecodecall9998 5 \luabytecodecall5555 5sp

```



The variable `s` in the code is the number of the byte code register that can be used for diagnostic purposes. The advantage of bytecode registers over function calls is that they are stored in the format (but without upvalues).

2.5 Catcode tables

2.5.1 Catcodes

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. This subsystem is backward compatible: if you never use the following commands, your document will not notice any difference in behaviour compared to traditional \TeX . The contents of each catcode table is independent from any other catcode table, and its contents is stored and retrieved from the format file.

2.5.2 `\catcodetable`

`\catcodetable` <15-bit number>

The primitive `\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 `ini \TeX` .

2.5.3 `\initcatcodetable`

`\initcatcodetable` <15-bit number>

The primitive `\initcatcodetable` creates a new table with catcodes identical to those defined by `ini \TeX` . 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. The initial values are:

| CATCODE | CHARACTER | EQUIVALENT | CATEGORY |
|---------|----------------------------|------------|--------------|
| 0 | <code>\</code> | | escape |
| 5 | <code>^^M</code> | return | car_ret |
| 9 | <code>^^@</code> | null | ignore |
| 10 | <code><space></code> | space | spacer |
| 11 | <code>a - z</code> | | letter |
| 11 | <code>A - Z</code> | | letter |
| 12 | everything else | | other |
| 14 | <code>%</code> | | comment |
| 15 | <code>^^?</code> | delete | invalid_char |

2.5.4 `\savecatcodetable`

`\savecatcodetable` <15-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.

2.6 Suppressing errors

2.6.1 `\suppressfontnotfounderror`

If this integer parameter is non-zero, then Lua \TeX 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.

```
\suppressfontnotfounderror = 1
```

2.6.2 `\suppresslongerror`

If this integer parameter is non-zero, then Lua \TeX will not complain about `\par` commands encountered in contexts where that is normally prohibited (most prominently in the arguments of macros not defined as `\long`).

```
\suppresslongerror = 1
```

2.6.3 `\suppressifcsnameerror`

If this integer parameter is non-zero, then Lua \TeX will not complain about non-expandable commands appearing in the middle of a `\ifcsname` expansion. Instead, it will keep getting expanded tokens from the input until it encounters an `\endcsname` command. If the input expansion is unbalanced with respect to `\csname ... \endcsname` pairs, the Lua \TeX process may hang indefinitely.

```
\suppressifcsnameerror = 1
```

2.6.4 `\suppressoutererror`

If this new integer parameter is non-zero, then Lua \TeX will not complain about `\outer` commands encountered in contexts where that is normally prohibited.

```
\suppressoutererror = 1
```

2.6.5 `\suppressmathparerror`

The following setting will permit `\par` tokens in a math formula:

```
\suppressmathparerror = 1
```

So, the next code is valid then:

```
$ x + 1 =
```



a \$

2.6.6 `\suppressprimitiveerror`

When set to a non-zero value the following command will not issue an error:

```
\suppressprimitiveerror = 1
\primitive\notapimitive
```

2.7 Fonts

2.7.1 Font syntax

Lua \TeX 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.

2.7.2 `\fontid` and `\setfontid`

```
\fontid\font
```

This primitive expands into a number. It is not a register so there is no need to prefix with `\number` (and using `\the` gives an error). The currently used font id is 29. Here are some more:

| STYLE | COMMAND | FONT ID |
|-------------|------------------|------------------|
| normal | <code>\tf</code> | 38 |
| bold | <code>\bf</code> | 38 |
| italic | <code>\it</code> | <i>50</i> |
| bold italic | <code>\bi</code> | <i>51</i> |

These numbers depend on the macro package used because each one has its own way of dealing with fonts. They can also differ per run, as they can depend on the order of loading fonts. For instance, when in Con \TeX t virtual math Unicode fonts are used, we can easily get over a hundred ids in use. Not all ids have to be bound to a real font, after all it's just a number.

The primitive `\setfontid` can be used to enable a font with the given id, which of course needs to be a valid one.

2.7.3 `\noligs` and `\nokerns`

These primitives prohibit ligature and kerning insertion at the time when the initial node list is built by Lua \TeX 's main control loop. You can 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>

These primitives can also be implemented by overloading the ligature building and kerning functions, i.e. by assigning dummy functions to their associated callbacks. Keep in mind that when you define a font (using Lua) you can also omit the kern and ligature tables, which has the same effect as the above.

2.7.4 `\nospaces`

This new primitive can be used to overrule the usual `\spaceskip` related heuristics when a space character is seen in a text flow. The value 1 triggers no injection while 2 results in injection of a zero skip. In figure 2.1 we see the results for four characters separated by a space.

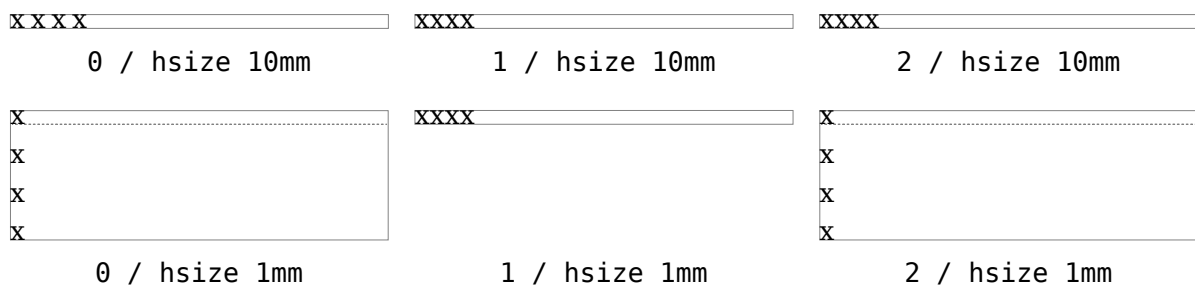


Figure 2.1 The `\nospaces` options.

2.8 Tokens, commands and strings

2.8.1 `\scantextokens`

The syntax of `\scantextokens` is identical to `\scantokens`. This primitive 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.
- ▶ There are no ‘... while end of file ...’ error tests executed. This allows the expansion to end on a different grouping level or while a conditional is still incomplete.

2.8.2 `\toksapp`, `\tokspre`, `\etoksapp`, `\etokspre`, `\gtoksapp`, `\gtokspre`, `\xtoksapp`, `\xtokspre`

Instead of:

```
\toks0\expandafter{\the\toks0 foo}
```

you can use:

```
\etoksapp0{foo}
```



The `pre` variants prepend instead of append, and the `e` variants expand the passed general text. The `g` and `x` variants are global.

2.8.3 `\csstring`, `\begincsname` and `\lastnamedcs`

These are somewhat special. The `\csstring` primitive is like `\string` but it omits the leading escape character. This can be somewhat more efficient than stripping it afterwards.

The `\begincsname` primitive is like `\csname` but doesn't create a relaxed equivalent when there is no such name. It is equivalent to

```
\ifcsname foo\endcsname
  \csname foo\endcsname
\fi
```

The advantage is that it saves a lookup (don't expect much speedup) but more important is that it avoids using the `\if` test. The `\lastnamedcs` is one that should be used with care. The above example could be written as:

```
\ifcsname foo\endcsname
  \lastnamedcs
\fi
```

This is slightly more efficient than constructing the string twice (deep down in LuaTeX this also involves some utf8 juggling), but probably more relevant is that it saves a few tokens and can make code a bit more readable.

2.8.4 `\clearmarks`

This primitive complements the ε -TeX mark primitives and clears a mark class completely, resetting all three connected mark texts to empty. It is an immediate command.

```
\clearmarks <16-bit number>
```

2.8.5 `\alignmark` and `\aligntab`

The primitive `\alignmark` duplicates the functionality of `#` inside alignment preambles, while `\aligntab` duplicates the functionality of `&`.

2.8.6 `\letcharcode`

This primitive can be used to assign a meaning to an active character, as in:

```
\def\foo{bar} \letcharcode123=\foo
```

This can be a bit nicer than using the uppercase tricks (using the property of `\uppercase` that it treats active characters special).



2.8.7 `\glet`

This primitive is similar to:

```
\protected\def\glet{\global\let}
```

but faster (only measurable with millions of calls) and probably more convenient (after all we also have `\gdef`).

2.8.8 `\expanded`, `\immediateassignment` and `\immediateassigned`

The `\expanded` primitive takes a token list and expands its content which can come in handy: it avoids a tricky mix of `\expandafter` and `\noexpand`. You can compare it with what happens inside the body of an `\edef`. But this kind of expansion still doesn't expand some primitive operations.

```
\newcount\NumberOfCalls
```

```
\def\TestMe{\advance\NumberOfCalls1 }
```

```
\edef\Tested{\TestMe foo:\the\NumberOfCalls}
```

```
\edef\Tested{\TestMe foo:\the\NumberOfCalls}
```

```
\edef\Tested{\TestMe foo:\the\NumberOfCalls}
```

```
\meaning\Tested
```

The result is a macro that has the not expanded code in its body:

```
macro:->\advance \NumberOfCalls 1 foo:0
```

Instead we can define `\TestMe` in a way that expands the assignment immediately. You need of course to be aware of preventing look ahead interference by using a space or `\relax` (often an expression works better as it doesn't leave an `\relax`).

```
\def\TestMe{\immediateassignment\advance\NumberOfCalls1 }
```

```
\edef\Tested{\TestMe foo:\the\NumberOfCalls}
```

```
\edef\Tested{\TestMe foo:\the\NumberOfCalls}
```

```
\edef\Tested{\TestMe foo:\the\NumberOfCalls}
```

```
\meaning\Tested
```

This time the counter gets updated and we don't see interference in the resulting `\Tested` macro:

```
macro:->foo:3
```

Here is a somewhat silly example of expanded comparison:

```
\def\expandeddoifelse#1#2#3#4%  
  {\immediateassignment\edef\tempa{#1}%  
   \immediateassignment\edef\tempb{#2}%
```



```

\ifx\tempa\tempb
  \immediateassignment\def\next{#3}%
\else
  \immediateassignment\def\next{#4}%
\fi
\next}

```

```

\edef\Tested
{(\expandeddoifelse{abc}{def}{yes}{nop})/%
  \expandeddoifelse{abc}{abc}{yes}{nop})}

```

```
\meaning\Tested
```

It gives:

```
macro:->(nop/yes)
```

A variant is:

```

\def\expandeddoifelse#1#2#3#4%
{\immediateassigned{
  \edef\tempa{#1}%
  \edef\tempb{#2}%
}%
\ifx\tempa\tempb
  \immediateassignment\def\next{#3}%
\else
  \immediateassignment\def\next{#4}%
\fi
\next}

```

The possible error messages are the same as using assignments in preambles of alignments and after the `\accent` command. The supported assignments are the so called prefixed commands (except box assignments).

2.8.9 `\ifcondition`

This is a somewhat special one. When you write macros conditions need to be properly balanced in order to let $\text{T}_{\text{E}}\text{X}$'s fast branch skipping work well. This new primitive is basically a no-op flagged as a condition so that the scanner can recognize it as an if-test. However, when a real test takes place the work is done by what follows, in the next example `\something`.

```

\unexpanded\def\something#1#2%
{\edef\tempa{#1}%
  \edef\tempb{#2}
  \ifx\tempa\tempb}

\ifcondition\something{a}{b}%
  \ifcondition\something{a}{a}%

```



```

        true 1
    \else
        false 1
    \fi
\else
    \ifcondition\something{a}{a}%
        true 2
    \else
        false 2
    \fi
\fi

```

If you are familiar with MetaPost, this is a bit like `vardef` where the macro has a return value. Here the return value is a test.

2.9 Boxes, rules and leaders

2.9.1 `\outputbox`

This integer parameter allows you to alter the number of the box that will be used to store the page sent to the output routine. Its default value is 255, and the acceptable range is from 0 to 65535.

```
\outputbox = 12345
```

2.9.2 `\vpack`, `\hpack` and `\tpack`

These three primitives are like `\vbox`, `\hbox` and `\vtop` but don't apply the related callbacks.

2.9.3 `\vsplit`

The `\vsplit` primitive has to be followed by a specification of the required height. As alternative for the `to` keyword you can use `upto` to get a split of the given size but result has the natural dimensions then. If `\ignoreprimitiveerror = 1`, the error "Infinite glue shrinkage found in box being split" that occurs when `vsplit`-ting a box containing infinite negative glue is turned into a warning.

2.9.4 Images and reused box objects

These two concepts are now core concepts and no longer whatsits. They are in fact now implemented as rules with special properties. Normal rules have subtype 0, saved boxes have subtype 1 and images have subtype 2. This has the positive side effect that whenever we need to take content with dimensions into account, when we look at rule nodes, we automatically also deal with these two types.



The syntax of the `\save...resource` is the same as in pdfTeX but you should consider them to be backend specific. This means that a macro package should treat them as such and check for the current output mode if applicable.

| COMMAND | EXPLANATION |
|---|--|
| <code>\saveboxresource</code> | save the box as an object to be included later |
| <code>\saveimageresource</code> | save the image as an object to be included later |
| <code>\useboxresource</code> | include the saved box object here (by index) |
| <code>\useimageresource</code> | include the saved image object here (by index) |
| <code>\lastsavedboxresourceindex</code> | the index of the last saved box object |
| <code>\lastsavedimageresourceindex</code> | the index of the last saved image object |
| <code>\lastsavedimageresourcepages</code> | the number of pages in the last saved image object |

LuaTeX accepts optional dimension parameters for `\use...resource` in the same format as for rules. With images, these dimensions are then used instead of the ones given to `\useimageresource` but the original dimensions are not overwritten, so that a `\useimageresource` without dimensions still provides the image with dimensions defined by `\saveimageresource`. These optional parameters are not implemented for `\saveboxresource`.

```
\useimageresource width 20mm height 10mm depth 5mm \lastsavedimageresourceindex
\useboxresource width 20mm height 10mm depth 5mm \lastsavedboxresourceindex
```

The box resources are of course implemented in the backend and therefore we do support the `attr` and `resources` keys that accept a token list. New is the `type` key. When set to non-zero the `/Type` entry is omitted. A value of 1 or 3 still writes a `/BBox`, while 2 or 3 will write a `/Matrix`.

2.9.5 `\nohrule` and `\novrule`

Because introducing a new keyword can cause incompatibilities, two new primitives were introduced: `\nohrule` and `\novrule`. These can be used to reserve space. This is often more efficient than creating an empty box with fake dimensions.

2.9.6 `\gleaders`

This type of leaders is anchored to the origin of the box to be shipped out. So they are like normal `\leaders` in that they align nicely, except that the alignment is based on the *largest* enclosing box instead of the *smallest*. The `g` stresses this global nature.

2.10 Languages

2.10.1 `\hyphenationmin`

This primitive can be used to set the minimal word length, so setting it to a value of 5 means that only words of 6 characters and more will be hyphenated, of course within the constraints of the `\lefthyphenmin` and `\righthyphenmin` values (as stored in the glyph node). This primitive accepts a number and stores the value with the language.



2.10.2 `\boundary`, `\noboundary`, `\protrusionboundary` and `\wordboundary`

The `\noboundary` command is used to inject a whatsit node but now injects a normal node with type boundary and subtype 0. In addition you can say:

```
x\boundary 123\relax y
```

This has the same effect but the subtype is now 1 and the value 123 is stored. The traditional ligature builder still sees this as a cancel boundary directive but at the Lua end you can implement different behaviour. The added benefit of passing this value is a side effect of the generalization. The subtypes 2 and 3 are used to control protrusion and word boundaries in hyphenation and have related primitives.

2.10.3 `\glyphdimensionsmode`

Already in the early days of LuaTeX the decision was made to calculate the effective height and depth of glyphs in a way that reflected the applied vertical offset. The height got that offset added, the depth only when the offset was larger than zero. We can now control this in more detail with this mode parameter. An offset is added to the height and/or subtracted from the depth. The effective values are never negative. The zero mode is the default.

| VALUE | EFFECT |
|-------|--|
| 0 | the old behaviour: add the offset to the height and only subtract the offset only from the depth when it is positive |
| 1 | add the offset to the height and subtract it from the depth |
| 2 | add the offset to the height and subtract it from the depth but keep the maxima of the current and previous results |
| 3 | use the height and depth of the glyph, so no offset is applied |

2.11 Control and debugging

2.11.1 Tracing

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

2.11.2 `\outputmode`

The `\outputmode` variable tells LuaTeX what it has to produce:

| VALUE | OUTPUT |
|-------|----------|
| 0 | dvi code |
| 1 | pdf code |



2.11.3 `\draftmode`

The value of the `\draftmode` counter signals the backend if it should output less. The pdf backend accepts a value of 1, while the dvi backend ignores the value. This is no critical feature so we can remove it in future versions when it can make the backend cleaner.

2.12 Files

2.12.1 File syntax

LuaTeX will accept a braced argument as a file name:

```
\input {plain}
\openin 0 {plain}
```

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

The `\tracingfonts` primitive that has been inherited from pdfTeX has been adapted to support variants in reporting the font. The reason for this extension is that a csname not always makes sense. The zero case is the default.

| VALUE | REPORTED |
|-------|---|
| 0 | <code>\foo xyz</code> |
| 1 | <code>\foo (bar)</code> |
| 2 | <code><bar> xyz</code> |
| 3 | <code><bar @ ..pt> xyz</code> |
| 4 | <code><id></code> |
| 5 | <code><id: bar></code> |
| 6 | <code><id: bar @ ..pt> xyz</code> |

2.12.2 Writing to file

You can now open upto 127 files with `\openout`. When no file is open writes will go to the console and log. As a consequence a system command is no longer possible but one can use `os.execute` to do the same.

2.13 Math

We will cover math extensions in its own chapter because not only the font subsystem and spacing model have been enhanced (thereby introducing many new primitives) but also because some more control has been added to existing functionality. Much of this relates to the different approaches of traditional TeX fonts and OpenType math.





3 Modifications

3.1 The merged engines

3.1.1 The need for change

The first version of LuaT_EX only had a few extra primitives and it was largely the same as pdfT_EX. Then we merged substantial parts of Aleph into the code and got more primitives. When we got more stable the decision was made to clean up the rather hybrid nature of the program. This means that some primitives have been promoted to core primitives, often with a different name, and that others were removed. This made it possible to start cleaning up the code base. In chapter 2 we discussed some new primitives, here we will cover most of the adapted ones.

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. These will also be mentioned.

3.1.2 Changes from T_EX 3.1415926

Of course it all starts with traditional T_EX. Even if we started with pdfT_EX, most still comes from the original. But we divert a bit.

- ▶ The current code base is written in C, not Pascal. We use cweb when possible. As a consequence instead of one large file plus change files, we now have multiple files organized in categories like tex, pdf, lang, font, lua, etc. There are some artifacts of the conversion to C, but in due time we will clean up the source code and make sure that the documentation is done right. Many files are in the cweb format, but others, like those interfacing to Lua, are C files. Of course we want to stay as close as possible to the original so that the documentation of the fundamentals behind T_EX by Don Knuth still applies.
- ▶ See chapter 5 for many small changes related to paragraph building, language handling and hyphenation. The most important change is that adding a brace group in the middle of a word (like in of{ }fice) does not prevent ligature creation.
- ▶ There is no pool file, all strings are embedded during compilation.
- ▶ The specifier plus 1 filllll does not generate an error. The extra 'l' is simply typeset.
- ▶ The upper limit to \endlinechar and \newlinechar is 127.
- ▶ Magnification (\mag) is only supported in dvi output mode. You can set this parameter and it even works with true units till you switch to pdf output mode. When you use pdf output you can best not touch the \mag variable. This fuzzy behaviour is not much different from using pdf backend related functionality while eventually dvi output is required.
After the output mode has been frozen (normally that happens when the first page is shipped out) or when pdf output is enabled, the true specification is ignored. When you preload a plain format adapted to LuaT_EX it can be that the \mag parameter already has been set.
- ▶ When \globaldefs is positive while a local assignment is asked for, {\global enforced} is shown in the log when \tracingcommands is larger than one. When \globaldefs is negative



and a global assignment is requested by `\global`, `\gdef` etc. the log will mention `{\global canceled}`.

3.1.3 Changes from ϵ -TeX 2.2

Being the de facto standard extension of course we provide the ϵ -TeX functionality, but with a few small adaptations.

- ▶ The ϵ -TeX functionality is always present and enabled so the prepended asterisk or `-etex` switch for `iniTeX` is not needed.
- ▶ The `TeXXeT` extension is not present, so the primitives `\TeXXeTstate`, `\beginR`, `\beginL`, `\endR` and `\endL` are missing. Instead we used the Omega/Aleph approach to directionality as starting point.
- ▶ Some of the tracing information that is output by ϵ -TeX's `\tracingassigns` and `\tracingrestores` is not there.
- ▶ Register management in LuaTeX uses the Omega/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.
- ▶ When `kpathsea` is used to find files, LuaTeX uses the `ofm` file format to search for font metrics. In turn, this means that LuaTeX looks at the `OFM FONTS` configuration variable (like Omega and Aleph) instead of `TFM FONTS` (like TeX and pdfTeX). Likewise for virtual fonts (LuaTeX uses the variable `OVFFONTS` instead of `VFFONTS`).
- ▶ The primitives that report a stretch or shrink order report a value in a convenient range zero upto four. Because some macro packages can break on that we also provide `\TeXgluestretchorder` and `\TeXglueshrinkorder` which report values compatible with ϵ -TeX. The (new) `fi` value is reported as `-1` (so when used in an `\ifcase` test that value makes one end up in the `\else`).

3.1.4 Changes from PDFTeX 1.40

Because we want to produce pdf the most natural starting point was the popular pdfTeX program. We inherit the stable features, dropped most of the experimental code and promoted some functionality to core LuaTeX functionality which in turn triggered renaming primitives.

For compatibility reasons we still refer to `\pdf . . .` commands but LuaTeX has a different backend interface. Instead of these primitives there are three interfacing primitives: `\pdfextension`, `\pdfvariable` and `\pdffeedback` that take keywords and optional further arguments (below we will still use the `\pdf` prefix names as reference). This way we can extend the features when needed but don't need to adapt the core engine. The front- and backend are decoupled as much as possible.

- ▶ 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 gone are: `\pdfsnaprefpoint`, `\pdfsnapy`, and `\pdfsnapycomp`.
- ▶ The (experimental) support for specialized spacing around nodes has also been removed. The associated primitives that are gone are: `\pdfadjustinterwordglue`, `\pdfprependkern`, and



`\pdfappendkern`, as well as the five supporting primitives `\knbscode`, `\stbscode`, `\shbscode`, `\knbccode`, and `\knaccode`.

- ▶ A number of ‘pdf_{TeX} primitives’ have been removed as they can be implemented using Lua: `\pdfelapstimer`, `\pdfescapehex`, `\pdfescapename`, `\pdfescapestring`, `\pdffile-dump`, `\pdffilemoddate`, `\pdffilesize`, `\pdfforcepagebox`, `\pdflastmatch`, `\pdfmatch`, `\pdfmdfivesum`, `\pdfmovechars`, `\pdfoptionalwaysusepdfpagebox`, `\pdfoptionpdfinclusionerrorlevel`, `\pdfresettimer`, `\pdfshellescape`, `\pdfstrcmp` and `\pdfunescapehex`.
- ▶ The version related primitives `\pdftebanner`, `\pdfteversion` and `\pdfterevision` are no longer present as there is no longer a relationship with pdf_{TeX} development.
- ▶ The experimental snapper mechanism has been removed and therefore also the primitives `\pdfignoreddimen`, `\pdffirstlineheight`, `\pdfeachlineheight`, `\pdfeachlinedepth` and `\pdflastlinedepth`.
- ▶ The experimental primitives `\primitive`, `\ifprimitive`, `\ifabsnum` and `\ifabsdim` are promoted to core primitives. The `\pdf*` prefixed originals are not available.
- ▶ Because Lua_{TeX} has a different subsystem for managing images, more diversion from its ancestor happened in the meantime. We don’t adapt to changes in pdf_{TeX}.
- ▶ Two extra token lists are provided, `\pdfxformresources` and `\pdfxformattr`, as an alternative to `\pdfxform` keywords.
- ▶ Image specifications also support `visiblefilename`, `userpassword` and `ownerpassword`. The password options are only relevant for encrypted pdf files.
- ▶ The current version of Lua_{TeX} no longer replaces and/or merges fonts in embedded pdf files with fonts of the enveloping pdf document. This regression may be temporary, depending on how the rewritten font backend will look like.
- ▶ The primitives `\pdfpagewidth` and `\pdfpageheight` have been removed because `\pagewidth` and `\pageheight` have that purpose.
- ▶ The primitives `\pdfnormaldeviate`, `\pdfuniformdeviate`, `\pdfsetrandomseed` and `\pdfrandomseed` have been promoted to core primitives without pdf prefix so the original commands are no longer recognized.
- ▶ The primitives `\ifincsname`, `\expanded` and `\quitvmode` are now core primitives.
- ▶ As the hz and protrusion mechanism are part of the core the related primitives `\lrcode`, `\rrcode`, `\efcode`, `\leftmarginkern`, `\rightmarginkern` are promoted to core primitives. The two commands `\protrudechars` and `\adjustspacing` replace their prefixed with `\pdf` originals.
- ▶ The hz optimization code has been partially redone so that we no longer need to create extra font instances. The front- and backend have been decoupled and more efficient (pdf) code is generated.
- ▶ When `\adjustspacing` has value 2, hz optimization will be applied to glyphs and kerns. When the value is 3, only glyphs will be treated. A value smaller than 2 disables this feature. With value of 1, font expansion is applied after _{TeX}’s normal paragraph breaking routines have broken the paragraph into lines. In this case, line breaks are identical to standard _{TeX} behavior (as with pdf_{TeX}).
- ▶ The `\tagcode` primitive is promoted to core primitive.
- ▶ The `\letterspacefont` feature is now part of the core but will not be changed (improved). We just provide it for legacy use.
- ▶ The `\pdfnoligatures` primitive is now `\ignoreligaturesinfont`.
- ▶ The `\pdfcopyfont` primitive is now `\copyfont`.



- ▶ The `\pdffontexpand` primitive is now `\expandglyphsinfont`.
- ▶ Because position tracking is also available in dvi mode the `\savepos`, `\lastxpos` and `\lastypos` commands now replace their pdf prefixed originals.
- ▶ The introspective primitives `\pdflastximagecolordepth` and `\pdfximagebbox` have been removed. One can use external applications to determine these properties or use the built-in `img` library.
- ▶ The initializers `\pdfoutput` has been replaced by `\outputmode` and `\pdfdraftmode` is now `\draftmode`.
- ▶ The pixel multiplier dimension `\pdfpxdimen` lost its prefix and is now called `\pxdimen`.
- ▶ An extra `\pdfimageaddfilename` option has been added that can be used to block writing the filename to the pdf file.
- ▶ The primitive `\pdftracingfonts` is now `\tracingfonts` as it doesn't relate to the backend.
- ▶ The experimental primitive `\pdfinsertht` is kept as `\insertht`.
- ▶ There is some more control over what metadata goes into the pdf file.
- ▶ The promotion of primitives to core primitives as well as the separation of font- and backend means that the initialization namespace `pdftex` is gone.

One change involves the so called `xforms` and `ximages`. In pdf \TeX these are implemented as so called `whatsits`. But contrary to other `whatsits` they have dimensions that need to be taken into account when for instance calculating optimal line breaks. In Lua \TeX these are now promoted to a special type of rule nodes, which simplifies code that needs those dimensions.

Another reason for promotion is that these are useful concepts. Backends can provide the ability to use content that has been rendered in several places, and images are also common. As already mentioned in section 2.9.4, we now have:

| LUAT \TeX | PDF \TeX |
|---|----------------------------------|
| <code>\saveboxresource</code> | <code>\pdfxform</code> |
| <code>\saveimageresource</code> | <code>\pdfximage</code> |
| <code>\useboxresource</code> | <code>\pdfrefxform</code> |
| <code>\useimageresource</code> | <code>\pdfrefximage</code> |
| <code>\lastsavedboxresourceindex</code> | <code>\pdflastxform</code> |
| <code>\lastsavedimageresourceindex</code> | <code>\pdflastximage</code> |
| <code>\lastsavedimageresourcepages</code> | <code>\pdflastximagepages</code> |

There are a few `\pdffeedback` features that relate to this but these are typical backend specific ones. The index that gets returned is to be considered as 'just a number' and although it still has the same meaning (object related) as before, you should not depend on that.

The protrusion detection mechanism is enhanced a bit to enable a bit more complex situations. When protrusion characters are identified some nodes are skipped:

- ▶ zero glue
- ▶ penalties
- ▶ empty discretionaries
- ▶ normal zero kerns
- ▶ rules with zero dimensions
- ▶ math nodes with a surround of zero
- ▶ dir nodes
- ▶ empty horizontal lists
- ▶ local par nodes
- ▶ inserts, marks and adjusts
- ▶ boundaries
- ▶ whatsits



Because this can not be enough, you can also use a protrusion boundary node to make the next node being ignored. When the value is 1 or 3, the next node will be ignored in the test when locating a left boundary condition. When the value is 2 or 3, the previous node will be ignored when locating a right boundary condition (the search goes from right to left). This permits protrusion combined with for instance content moved into the margin:

```
\protrusionboundary1\llap{!\quad}«Who needs protrusion?»
```

3.1.5 Changes from ALEPH RC4

Because we wanted proper directional typesetting the Aleph mechanisms looked most attractive. These are rather close to the ones provided by Omega, so what we say next applies to both these programs.

- ▶ The extended 16-bit math primitives (`\omathcode` etc.) have been removed.
- ▶ The OCP processing has been removed completely and as a consequence, the following primitives have been removed: `\ocp`, `\externalocp`, `\ocplist`, `\pushocplist`, `\popocplist`, `\clearocplists`, `\addbeforeocplist`, `\addafterocplist`, `\removebeforeocplist`, `\removeafterocplist` and `\ocptracelevel`.
- ▶ LuaTeX only understands 4 of the 16 direction specifiers of Aleph: TLT (latin), TRT (arabic), RTT (CJK), LTL (mongolian). All other direction specifiers generate an error. In addition to a keyword driven model we also provide an integer driven one.
- ▶ 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` and `\OutputTranslation`.
- ▶ Several bugs have been fixed and confusing implementation details have been sorted out.
- ▶ The scanner for direction specifications now allows an optional space after the direction is completely parsed.
- ▶ The `^^` notation has been extended: after `^^^^` four hexadecimal characters are expected and after `^^^^^^` six hexadecimal characters have to be given. The original TeX interpretation is still valid for the `^^` case but the four and six variants do no backtracking, i.e. when they are not followed by the right number of hexadecimal digits they issue an error message. Because `^^` is a normal TeX case, we don't support the odd number of `^^^^^^` either.
- ▶ Glues *immediately after* direction change commands are not legal breakpoints.
- ▶ Several mechanisms that need to be right-to-left aware have been improved. For instance placement of formula numbers.
- ▶ The page dimension related primitives `\pagewidth` and `\pageheight` have been promoted to core primitives. The `\hoffset` and `\voffset` primitives have been fixed.
- ▶ The primitives `\charwd`, `\charht`, `\chardp` and `\charit` have been removed as we have the ϵ -TeX variants `\fontchar*`.
- ▶ The two dimension registers `\pagerightoffset` and `\pagebottomoffset` are now core primitives.
- ▶ The direction related primitives `\pagedir`, `\bodydir`, `\pardir`, `\textdir`, `\mathdir` and `\boxdir` are now core primitives.



- ▶ The promotion of primitives to core primitives as well as removing of all others means that the initialization namespace `aleph` that early versions of LuaTeX provided is gone.

The above let's itself summarize as: we took the 32 bit aspects and much of the directional mechanisms and merged it into the pdfTeX code base as starting point for further development. Then we simplified directionality, fixed it and opened it up.

3.1.6 Changes from anywhere

The `\partokenname` and `\partokencontext` primitives are taken from the pdfTeX change file posted on the implementers list. They are explained in the pdfTeX manual and are classified as ϵ -TeX extensions.

3.1.7 Changes from standard WEB2C

The compilation framework is `web2c` and we keep using that but without the Pascal to C step. This framework also provides some common features that deal with reading bytes from files and locating files in `tds`. This is what we do different:

- ▶ There is no `mltex` support.
- ▶ There is no `enctex` support.
- ▶ The following encoding related command line switches are silently ignored, even in non-Lua mode: `-8bit`, `-translate-file`, `-mltex`, `-enc` and `-etex`.
- ▶ The `\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` and alike.
- ▶ The 'E' option does not do anything useful.

3.2 The backend primitives

3.2.1 Less primitives

In a previous section we mentioned that some pdfTeX primitives were removed and others promoted to core LuaTeX primitives. That is only part of the story. In order to separate the backend specific primitives in the code these commands are now replaced by only a few. In traditional TeX we only had the `dvi` backend but now we have two: `dvi` and `pdf`. Additional functionality is implemented as 'extensions' in TeX speak. By separating more strictly we are able to keep the core (frontend) clean and stable and isolate these extensions. If for some reason an extra backend option is needed, it can be implemented without touching the core. The three pdf backend related primitives are:

```
\pdfextension command [specification]
\pdfvariable name
```



`\pdffeedback name`

An extension triggers further parsing, depending on the command given. A variable is a (kind of) register and can be read and written, while a feedback is reporting something (as it comes from the backend it's normally a sequence of tokens).

3.2.2 `\pdfextension`, `\pdfvariable` and `\pdffeedback`

In order for Lua \TeX to be more than just \TeX you need to enable primitives. That has already been the case right from the start. If you want the traditional pdf \TeX primitives (for as far their functionality is still around) you now can do this:

```
\protected\def\pdfliteral           {\pdfextension literal}
\protected\def\pdflateliteral       {\pdfextension lateliteral}
\protected\def\pdfcolorstack        {\pdfextension colorstack}
\protected\def\pdfsetmatrix         {\pdfextension setmatrix}
\protected\def\pdfsave              {\pdfextension save\relax}
\protected\def\pdfrestore           {\pdfextension restore\relax}
\protected\def\pdfobj               {\pdfextension obj }
\protected\def\pdfrefobj            {\pdfextension refobj }
\protected\def\pdfannot             {\pdfextension annot }
\protected\def\pdfstartlink         {\pdfextension startlink }
\protected\def\pdfendlink           {\pdfextension endlink\relax}
\protected\def\pdfoutline           {\pdfextension outline }
\protected\def\pdfdest              {\pdfextension dest }
\protected\def\pdfthread            {\pdfextension thread }
\protected\def\pdfstartthread       {\pdfextension startthread }
\protected\def\pdfendthread         {\pdfextension endthread\relax}
\protected\def\pdfinfo              {\pdfextension info }
\protected\def\pdfcatalog           {\pdfextension catalog }
\protected\def\pdfnames             {\pdfextension names }
\protected\def\pdfincludechars      {\pdfextension includechars }
\protected\def\pdffontattr          {\pdfextension fontattr }
\protected\def\pdfmapfile           {\pdfextension mapfile }
\protected\def\pdfmapline           {\pdfextension mapline }
\protected\def\pdftrailer           {\pdfextension trailer }
\protected\def\pdfglyphtounicode    {\pdfextension glyphtounicode }
\protected\def\pdfrunninglinkoff    {\pdfextension linkstate 1 }
\protected\def\pdfrunninglinkon    {\pdfextension linkstate 0 }
```

The introspective primitives can be defined as:

```
\def\pdftexversion   {\numexpr\pdffeedback version\relax}
\def\pdftexrevision  {\pdffeedback revision}
\def\pdflastlink     {\numexpr\pdffeedback lastlink\relax}
\def\pdfretval       {\numexpr\pdffeedback retval\relax}
\def\pdflastobj      {\numexpr\pdffeedback lastobj\relax}
```



```

\def\pdflastannot      {\numexpr\pdffeedback lastannot\relax}
\def\pdfxformname      {\numexpr\pdffeedback xformname\relax}
\def\pdfcreationdate   {\pdffeedback creationdate}
\def\pdffontname       {\numexpr\pdffeedback fontname\relax}
\def\pdffontobjnum     {\numexpr\pdffeedback fontobjnum\relax}
\def\pdffontsize       {\dimexpr\pdffeedback fontsize\relax}
\def\pdfpageref        {\numexpr\pdffeedback pageref\relax}
\def\pdfcolorstackinit {\pdffeedback colorstackinit}

```

The configuration related registers have become:

```

\edef\pdfcompresslevel      {\pdfvariable compresslevel}
\edef\pdfobjcompresslevel   {\pdfvariable objcompresslevel}
\edef\pdfrecompress         {\pdfvariable recompress}
\edef\pdfdecimaldigits     {\pdfvariable decimaldigits}
\edef\pdfgamma              {\pdfvariable gamma}
\edef\pdfimageresolution   {\pdfvariable imageresolution}
\edef\pdfimageapplygamma   {\pdfvariable imageapplygamma}
\edef\pdfimagegamma        {\pdfvariable imagegamma}
\edef\pdfimagehicolor      {\pdfvariable imagehicolor}
\edef\pdfimageaddfilename  {\pdfvariable imageaddfilename}
\edef\pdfpkresolution      {\pdfvariable pkresolution}
\edef\pdfpkfixeddpi        {\pdfvariable pkfixeddpi}
\edef\pdfinclusioncopyfonts  {\pdfvariable inclusioncopyfonts}
\edef\pdfinclusionerrorlevel {\pdfvariable inclusionerrorlevel}
\edef\pdfignoreunknownimages {\pdfvariable ignoreunknownimages}
\edef\pdfgentounicode      {\pdfvariable gentounicode}
\edef\pdfomitcidset        {\pdfvariable omitcidset}
\edef\pdfomitcharset       {\pdfvariable omitcharset}
\edef\pdfomitinfodict      {\pdfvariable omitinfodict}
\edef\pdfomitinfodict      {\pdfvariable omitinfodict}
\edef\pdfomitmediabox      {\pdfvariable omitmediabox}
\edef\pdfomitprocset       {\pdfvariable omitprocset}
\edef\pdfptexprefix        {\pdfvariable ptexprefix}
\edef\pdfpagebox           {\pdfvariable pagebox}
\edef\pdfminorversion      {\pdfvariable minorversion}
\edef\pdfuniqueresname     {\pdfvariable uniqueresname}

\edef\pdfhorigin           {\pdfvariable horigin}
\edef\pdfvorigin           {\pdfvariable vorigin}
\edef\pdflinkmargin        {\pdfvariable linkmargin}
\edef\pdfdestmargin        {\pdfvariable destmargin}
\edef\pdfthreadmargin      {\pdfvariable threadmargin}
\edef\pdfxformmargin       {\pdfvariable xformmargin}

\edef\pdfpagesattr         {\pdfvariable pagesattr}
\edef\pdfpageattr          {\pdfvariable pageattr}

```



```

\edef\pdfpageresources      {\pdfvariable pageresources}
\edef\pdfxformattr         {\pdfvariable xformattr}
\edef\pdfxformresources    {\pdfvariable xformresources}
\edef\pdfpkmode            {\pdfvariable pkmode}

\edef\pdfsuppressoptionalinfo  {\pdfvariable suppressoptionalinfo }
\edef\pdftrailerid            {\pdfvariable trailerid }

```

The variables are internal ones, so they are anonymous. When you ask for the meaning of a few previously defined ones:

```

\meaning\pdfhorigin
\meaning\pdfcompresslevel
\meaning\pdfpageattr

```

you will get:

```

macro: ->[internal backend dimension]
macro: ->[internal backend integer]
macro: ->[internal backend tokenlist]

```

The `\edef` can also be a `\def` but it's a bit more efficient to expand the lookup related register beforehand.

The backend is derived from pdf \TeX so the same syntax applies. However, the `outline` command accepts a `objnum` followed by a number. No checking takes place so when this is used it had better be a valid (flushed) object.

In order to be (more or less) compatible with pdf \TeX we also support the option to suppress some info but we do so via a bitset:

```

\pdfvariable suppressoptionalinfo \numexpr
    0
    + 1  % PTEX.FullBanner
    + 2  % PTEX.FileName
    + 4  % PTEX.PageNumber
    + 8  % PTEX.InfoDict
    + 16 % Creator
    + 32 % CreationDate
    + 64 % ModDate
    + 128 % Producer
    + 256 % Trapped
    + 512 % ID
\relax

```

In addition you can overload the trailer id, but we don't do any checking on validity, so you have to pass a valid array. The following is like the ones normally generated by the engine. You even need to include the brackets here!

```

\pdfvariable trailerid {[

```



```

    <FA052949448907805BA83C1E78896398>
    <FA052949448907805BA83C1E78896398>
  ]}

```

Although we started from a merge of pdf_TE_X and Aleph, by now the code base as well as functionality has diverted from those parents. Here we show the options that can be passed to the extensions. The `shipout` option is a compatibility feature. Instead one can use the deferred prefix.

```

\pdfextension literal
  [shipout] [ direct | page | raw ] { tokens }

\pdfextension dest
  num integer | name { tokens }!crlf
  [ fitbh | fitbv | fitb | fith| fitv | fit |
    fitr <rule spec> | xyz [ zoom <integer> ]

\pdfextension annot
  reserveobjnum | useobjnum <integer>
  { tokens }

\pdfextension save

\pdfextension restore

\pdfextension setmatrix
  { tokens }

[ \immediate ] \pdfextension obj
  reserveobjnum

[ \immediate ] \pdfextension obj
  [ useobjnum <integer> ]
  [ uncompressed ]
  [ stream [ attr { tokens } ] ]
  [ file ]
  { tokens }

\pdfextension refobj
  <integer>

\pdfextension colorstack
  <integer>
  set { tokens } | push { tokens } | pop | current

\pdfextension startlink
  [ attr { tokens } ]
  user { tokens } | goto | thread
  [ file { tokens } ]
  [ page <integer> { tokens } | name { tokens } | num integer ]

```



```

    [ newwindow | nonewwindow ]
\pdfextension endlink
\pdfextension startthread
    num <integer> | name { tokens }
\pdfextension endthread
\pdfextension thread
    num <integer> | name { tokens }
\pdfextension outline
    [ attr { tokens } ]
    [ useobjnum <integer> ]
    [ count <integer> ]
    { tokens }
\pdfextension glyphtounicode
    { tokens }
    { tokens }
\pdfextension catalog
    { tokens }
    [ openaction
        user { tokens } | goto | thread
        [ file { tokens } ]
        [ page <integer> { tokens } | name { tokens } | num <integer> ]
        [ newwindow | nonewwindow ] ]
\pdfextension fontattr
    <integer>
    {tokens}
\pdfextension mapfile
    {tokens}
\pdfextension mapline
    {tokens}
\pdfextension includechars
    {tokens}
\pdfextension info
    {tokens}
\pdfextension names
    {tokens}
\pdfextension trailer

```



{tokens}

3.2.3 Defaults

The engine sets the following defaults.

| | |
|--------------------------------------|--------------------------|
| <code>\pdfcompresslevel</code> | 9 |
| <code>\pdfobjcompresslevel</code> | 1 % used: (0,9) |
| <code>\pdfrecompress</code> | 0 % mostly for debugging |
| <code>\pdfdecimaldigits</code> | 4 % used: (3,6) |
| <code>\pdfgamma</code> | 1000 |
| <code>\pdfimageresolution</code> | 71 |
| <code>\pdfimageapplygamma</code> | 0 |
| <code>\pdfimagegamma</code> | 2200 |
| <code>\pdfimagehicolor</code> | 1 |
| <code>\pdfimageaddfilename</code> | 1 |
| <code>\pdfpkresolution</code> | 72 |
| <code>\pdfpkfixeddpi</code> | 0 |
| <code>\pdfinclusioncopyfonts</code> | 0 |
| <code>\pdfinclusionerrorlevel</code> | 0 |
| <code>\pdfignoreunknownimages</code> | 0 |
| <code>\pdfgentounicode</code> | 0 |
| <code>\pdfomitcidset</code> | 0 |
| <code>\pdfomitcharset</code> | 0 |
| <code>\pdfomitinfodict</code> | 0 |
| <code>\pdfomitmediabox</code> | 0 |
| <code>\pdfomitprocset</code> | 0 |
| <code>\pdfpteprefix</code> | 0 |
| <code>\pdfpagebox</code> | 0 |
| <code>\pdfminorversion</code> | 4 |
| <code>\pdfuniqueresname</code> | 0 |
| | |
| <code>\pdfhorigin</code> | 1in |
| <code>\pdfvorigin</code> | 1in |
| <code>\pdflinkmargin</code> | 0pt |
| <code>\pdfdestmargin</code> | 0pt |
| <code>\pdfthreadmargin</code> | 0pt |
| <code>\pdfxformmargin</code> | 0pt |

3.2.4 Backward compatibility

If you also want some backward compatibility, you can add:

```
\let\pdfpagewidth \pagewidth
\let\pdfpageheight \pageheight

\let\pdfadjustspacing \adjustspacing
```



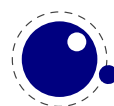
| | |
|--------------------------------------|---|
| <code>\let\pdfprotrudechars</code> | <code>\protrudechars</code> |
| <code>\let\pdfnoligatures</code> | <code>\ignoreligaturesinfont</code> |
| <code>\let\pdffontexpand</code> | <code>\expandglyphsinfont</code> |
| <code>\let\pdfcopyfont</code> | <code>\copyfont</code> |
| | |
| <code>\let\pdfxform</code> | <code>\saveboxresource</code> |
| <code>\let\pdflastxform</code> | <code>\lastsavedboxresourceindex</code> |
| <code>\let\pdfrefxform</code> | <code>\useboxresource</code> |
| | |
| <code>\let\pdfximage</code> | <code>\saveimageresource</code> |
| <code>\let\pdflastximage</code> | <code>\lastsavedimageresourceindex</code> |
| <code>\let\pdflastximagepages</code> | <code>\lastsavedimageresourcepages</code> |
| <code>\let\pdfrefximage</code> | <code>\useimageresource</code> |
| | |
| <code>\let\pdfsavepos</code> | <code>\savepos</code> |
| <code>\let\pdflastxpos</code> | <code>\lastxpos</code> |
| <code>\let\pdflastypos</code> | <code>\lastypos</code> |
| | |
| <code>\let\pdfoutput</code> | <code>\outputmode</code> |
| <code>\let\pdfdraftmode</code> | <code>\draftmode</code> |
| | |
| <code>\let\pdfpxdimen</code> | <code>\pxdimen</code> |
| | |
| <code>\let\pdfinsertht</code> | <code>\insertht</code> |
| | |
| <code>\let\pdfnormaldeviate</code> | <code>\normaldeviate</code> |
| <code>\let\pdfuniformdeviate</code> | <code>\uniformdeviate</code> |
| <code>\let\pdfsetrandomseed</code> | <code>\setrandomseed</code> |
| <code>\let\pdfrandomseed</code> | <code>\randomseed</code> |
| | |
| <code>\let\pdfprimitive</code> | <code>\primitive</code> |
| <code>\let\ifpdfprimitive</code> | <code>\ifprimitive</code> |
| | |
| <code>\let\ifpdfabsnum</code> | <code>\ifabsnum</code> |
| <code>\let\ifpdfabsdim</code> | <code>\ifabsdim</code> |

And even:

```

\newdimen\pdfeachlineheight
\newdimen\pdfeachlinedepth
\newdimen\pdflastlinedepth
\newdimen\pdffirstlineheight
\newdimen\pdfignoreddimen

```



3.3 Directions

3.3.1 Four directions

The directional model in Lua_T_EX is inherited from Omega/Aleph but we tried to improve it a bit. At some point we played with recovery of modes but that was disabled later on when we found that it interfered with nested directions. That itself had as side effect that the node list was no longer balanced with respect to directional nodes which in turn can give side effects when a series of dir changes happens without grouping.

When extending the pdf backend to support directions some inconsistencies were found and as a result we decided to support only the four models that make sense TLT (latin), TRT (arabic), RTT (cjk) and LTL (mongolian).

3.3.2 How it works

The approach is that we again make the list balanced but try to avoid some side effects. What happens is quite intuitive if we forget about spaces (turned into glue) but even there what happens makes sense if you look at it in detail. However that logic makes in-group switching kind of useless when no proper nested grouping is used: switching from right to left several times nested, results in spacing ending up after each other due to nested mirroring. Of course a sane macro package will manage this for the user but here we are discussing the low level dir injection.

This is what happens:

```
\textdir TRT nur {\textdir TLT run \textdir TRT NUR} nur
```

This becomes stepwise:

```
injected: [+TRT]nur {[+TLT]run [+TRT]NUR} nur
balanced: [+TRT]nur {[+TLT]run [-TLT][+TRT]NUR[-TRT]} nur[-TRT]
result   : run {RUNrun } run
```

And this:

```
\textdir TRT nur {nur \textdir TLT run \textdir TRT NUR} nur
```

becomes:

```
injected: [+TRT]nur {nur [+TLT]run [+TRT]NUR} nur
balanced: [+TRT]nur {nur [+TLT]run [-TLT][+TRT]NUR[-TRT]} nur[-TRT]
result   : run {run RUNrun } run
```

Now, in the following examples watch where we put the braces:

```
\textdir TRT nur {\{\textdir TLT run} {\textdir TRT NUR}} nur
```

This becomes:



run RUN run run

Compare this to:

```
\textdir TRT nur {\textdir TLT run }\textdir TRT NUR} nur
```

Which renders as:

run RUNrun run

So how do we deal with the next?

```
\def\ltr{\textdir TLT\relax}  
\def\rtl{\textdir TRT\relax}
```

```
run {\rtl nur {\ltr run \rtl NUR \ltr run \rtl NUR} nur}  
run {\ltr run {\rtl nur \ltr RUN \rtl nur \ltr RUN} run}
```

It gets typeset as:

run run RUNrun RUNrun run
run run runRUN runRUN run

We could define the two helpers to look back, pick up a skip, remove it and inject it after the dir node. But that way we lose the subtype information that for some applications can be handy to be kept as-is. This is why we now have a variant of `\textdir` which injects the balanced node before the skip. Instead of the previous definition we can use:

```
\def\ltr{\linedir TLT\relax}  
\def\rtl{\linedir TRT\relax}
```

and this time:

```
run {\rtl nur {\ltr run \rtl NUR \ltr run \rtl NUR} nur}  
run {\ltr run {\rtl nur \ltr RUN \rtl nur \ltr RUN} run}
```

comes out as a properly spaced:

run run RUN run RUN run run
run run run RUN run RUN run

Anything more complex than this, like combination of skips and penalties, or kerns, should be handled in the input or macro package because there is no way we can predict the expected behaviour. In fact, the `\linedir` is just a convenience extra which could also have been implemented using node list parsing.

Directions are complicated by the fact that they often need to work over groups so a separate grouping related stack is used. A side effect is that there can be paragraphs with only a local par node followed by direction synchronization nodes. Paragraphs like that are seen as empty paragraphs and therefore ignored. Because `\noindent` doesn't inject anything but a `\indent` injects a box, paragraphs with only an indent and directions are handled as paragraphs with content.



By default paragraphs before a display equation containing dir nodes are never ignored. Changing that could break existing documents, but when you set `\mathemptydisplaymode` to 1 empty paragraphs before a display equation will be ignored.

3.3.3 Controlling glue with `\breakafterdirmode`

Glue after a dir node is ignored in the linebreak decision but you can bypass that by setting `\breakafterdirmode` to 1. The following table shows the difference. Watch your spaces.

| | 0 | 1 |
|--|--------------------|--------------------|
| <code>pre {\textdir TLT xxx} post</code> | pre xxx post | pre xxx post |
| <code>pre {\textdir TLT xxx }post</code> | pre xxx post | pre xxx post |
| <code>pre{ \textdir TLT xxx} post</code> | pre xxx post | pre xxx post |
| <code>pre{ \textdir TLT xxx }post</code> | pre xxx post | pre xxx post |
| <code>pre { \textdir TLT xxx } post</code> | pre xxx post | pre xxx post |
| <code>pre {\textdir TLT\relax\space xxx} post</code> | pre xxx post | pre xxx post |

3.3.4 Controlling parshapes with `\shapemode`

Another adaptation to the Aleph directional model is control over shapes driven by `\hangindent` and `\parshape`. This is controlled by a new parameter `\shapemode`:

| VALUE | \HANGINDENT | \PARSHAPE |
|-------|-------------|-----------|
| 0 | normal | normal |
| 1 | mirrored | normal |
| 2 | normal | mirrored |
| 3 | mirrored | mirrored |

The value is reset to zero (like `\hangindent` and `\parshape`) after the paragraph is done with. You can use negative values to prevent this. In figure 3.1 a few examples are given.



We thrive in information–thick worlds because of our marvelous and everyday capacity to select, edit, single out, structure, highlight, group, pair, merge, harmonize, synthesize, focus, organize, condense, reduce, boil down, choose, categorize, catalog, classify, list, abstract, scan, look into, idealize, isolate, discriminate, distinguish, screen, pigeonhole, pick over, sort, integrate, blend, inspect, filter, lump, skip, smooth, chunk, average, approximate, cluster, aggregate, outline, summarize, itemize, review, dip into, flip through, browse, glance into, leaf through, skim, refine, enumerate, glean, synopsise, winnow the wheat from the chaff and separate the sheep from the goats.....

TLT: hangindent

We thrive in information–thick worlds because of our marvelous and everyday capacity to select, edit, single out, structure, highlight, group, pair, merge, harmonize, synthesize, focus, organize, condense, reduce, boil down, choose, categorize, catalog, classify, list, abstract, scan, look into, idealize, isolate, discriminate, distinguish, screen, pigeonhole, pick over, sort, integrate, blend, inspect, filter, lump, skip, smooth, chunk, average, approximate, cluster, aggregate, outline, summarize, itemize, review, dip into, flip through, browse, glance into, leaf through, skim, refine, enumerate, glean, synopsise, winnow the wheat from the chaff and separate the sheep from the goats.....

TLT: parshape

```
ruo fo esuaceb sdlrow kciht–noitamrofni ni evirht eW
-nis ,tide ,tceles ot yticapac yadyreve dna suolevram
-rah ,egrem ,riap ,puorg ,thgilhgih ,erutcurts ,tuo elg
,nwod liob ,ecuder ,esnednoc ,ezinagro ,sucof ,ezisehtnys ,ezinom
,otni kool ,nacs ,tcartsba ,tsil ,yfissalc ,golatac ,ezirogetac ,esoohc
kqip ,elohnoegip ,neercs ,hsiugnitsid ,etanimircsid ,etalosi ,ezilaedi
,knuhc ,htooms ,piks ,pmul ,retlfi ,tcepsni ,dnelb ,etargetni ,tros ,revo
-meti ,ezirammus ,eniltuo ,etagergga ,retsulc ,etamixorppa ,egareva
,hguorht fael ,otni ecnalg ,esworb ,hguorht pifl ,otni pid ,weiver ,ezi
morf taehw eht wonniw ,ezisponys ,naelg ,etaremune ,enfier ,miks
.....staog eht morf peehs eht. etarapes dna ffahc.eht.....
```

TRT: hangindent mode 0

```
-ram ruo fo esuaceb sdlrow kciht–noitamrofni ni evirht eW
,tuo elgnis ,tide ,tceles ot yticapac yadyreve dna suolev
-nys ,ezinomrah ,egrem ,riap ,puorg ,thgilhgih ,erutcurts
-ogetac ,esoohc ,nwod liob ,ecuder ,esnednoc ,ezinagro ,sucof ,eziseht
,etalosi ,ezilaedi ,otni kool ,nacs ,tcartsba ,tsil ,yfissalc ,golatac ,ezir
,etargetni ,tros ,revo kqip ,elohnoegip ,neercs ,hsiugnitsid ,etanimircsid
,etamixorppa ,egareva ,knuhc ,htooms ,piks ,pmul ,retlfi ,tcepsni ,dnelb
pifl ,otni pid ,weiver ,ezimeti ,ezirammus ,eniltuo ,etagergga ,retsulc
,etaremune ,enfier ,miks ,hguorht fael ,otni ecnalg ,esworb ,hguorht
eht etarapes dna ffahc eht morf taehw eht wonniw ,ezisponys ,naelg
.....staog eht morf peehs
```

TRT: parshape mode 0

```
ruo fo esuaceb sdlrow kciht–noitamrofni ni evirht eW
-nis ,tide ,tceles ot yticapac yadyreve dna suolevram
-rah ,egrem ,riap ,puorg ,thgilhgih ,erutcurts ,tuo elg
,nwod liob ,ecuder ,esnednoc ,ezinagro ,sucof ,ezisehtnys ,ezinom
,otni kool ,nacs ,tcartsba ,tsil ,yfissalc ,golatac ,ezirogetac ,esoohc
kqip ,elohnoegip ,neercs ,hsiugnitsid ,etanimircsid ,etalosi ,ezilaedi
,knuhc ,htooms ,piks ,pmul ,retlfi ,tcepsni ,dnelb ,etargetni ,tros ,revo
-meti ,ezirammus ,eniltuo ,etagergga ,retsulc ,etamixorppa ,egareva
,hguorht fael ,otni ecnalg ,esworb ,hguorht pifl ,otni pid ,weiver ,ezi
morf taehw eht wonniw ,ezisponys ,naelg ,etaremune ,enfier ,miks
.....staog eht morf peehs eht. etarapes dna ffahc.eht.....
```

TRT: hangindent mode 1 & 3

```
-ram ruo fo esuaceb sdlrow kciht–noitamrofni ni evirht eW
,tuo elgnis ,tide ,tceles ot yticapac yadyreve dna suolev
-nys ,ezinomrah ,egrem ,riap ,puorg ,thgilhgih ,erutcurts
-ogetac ,esoohc ,nwod liob ,ecuder ,esnednoc ,ezinagro ,sucof ,eziseht
,etalosi ,ezilaedi ,otni kool ,nacs ,tcartsba ,tsil ,yfissalc ,golatac ,ezir
,etargetni ,tros ,revo kqip ,elohnoegip ,neercs ,hsiugnitsid ,etanimircsid
,etamixorppa ,egareva ,knuhc ,htooms ,piks ,pmul ,retlfi ,tcepsni ,dnelb
pifl ,otni pid ,weiver ,ezimeti ,ezirammus ,eniltuo ,etagergga ,retsulc
,etaremune ,enfier ,miks ,hguorht fael ,otni ecnalg ,esworb ,hguorht
eht etarapes dna ffahc eht morf taehw eht wonniw ,ezisponys ,naelg
.....staog eht morf peehs
```

TRT: parshape mode 2 & 3

Figure 3.1 The effect of shapemode.

3.3.5 Symbols or numbers

Internally the implementation is different from Aleph. First of all we use no whatsits but dedicated nodes, but also we have only 4 directions that are mapped onto 4 numbers. A text direction node can mark the start or end of a sequence of nodes, and therefore has two states. At the $\text{T}_{\text{E}}\text{X}$ end we don't see these states because $\text{T}_{\text{E}}\text{X}$ itself will add proper end state nodes if needed.

The symbolic names TLT, TRT, etc. originate in Omega. In Lua $\text{T}_{\text{E}}\text{X}$ we also have a number based model which sometimes makes more sense.

| VALUE | EQUIVALENT |
|-------|------------|
| 0 | TLT |
| 1 | TRT |
| 2 | LTL |
| 3 | RTT |

We support the Omega primitives $\backslash\text{textdir}$, $\backslash\text{pardir}$, $\backslash\text{pagedir}$, $\backslash\text{mathdir}$ and $\backslash\text{mathdir}$. These accept three character keywords. The primitives that set the direction by number are: $\backslash\text{textdirection}$, $\backslash\text{pardirection}$, $\backslash\text{pagedirection}$ and $\backslash\text{bodydirection}$ and $\backslash\text{mathdirection}$. When specifying a direction for a box you can use bdir instead of dir .



3.4 Implementation notes

3.4.1 Memory allocation

The single internal memory heap that traditional T_EX 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 `texnode.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 macros have been duplicated. For instance, there are now `vlink` and `vinfo` as well as `token_link` and `token_info`. All access to the variable memory array is now hidden behind a macro called `vmem`. We mention this because using the T_EXbook as reference is still quite valid but not for memory related details. Another significant detail is that we have double linked node lists and that most nodes carry more data.

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.

3.4.2 Sparse arrays

The `\mathcode`, `\delcode`, `\catcode`, `\sfcode`, `\lccode` and `\uccode` (and the new `\hjcode`) tables are now sparse arrays that are implemented in C. They are no longer part of the T_EX ‘equivalence table’ and because each had 1.1 million entries with a few memory words each, this makes a major difference in memory usage. Performance is not really hurt by this.

The `\catcode`, `\sfcode`, `\lccode`, `\uccode` and `\hjcode` assignments don’t show up when using the ϵ -T_EX tracing routines `\tracingassigns` and `\tracingrestores` but we don’t see that as a real limitation.

A side-effect of the current implementation is that `\global` is now more expensive in terms of processing than non-global assignments but not many users will notice that.

The glyph ids within a font are also managed by means of a sparse array as glyph ids can go up to index $2^{21} - 1$ but these are never accessed directly so again users will not notice this.

3.4.3 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.



Active characters are internally implemented as a special type of multi-letter control sequences that uses a prefix that is otherwise impossible to obtain.

3.4.4 The compressed format file

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 io, so it should still be faster. We use a level 3 compression which we found to be the optimal trade-off between filesize and decompression speed.

3.4.5 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 io subsystem).

3.4.6 Tabs and spaces

We conform to the way other \TeX engines handle trailing tabs and spaces. For decades trailing tabs and spaces (before a newline) were removed from the input but this behaviour was changed in September 2017 to only handle spaces. We are aware that this can introduce compatibility issues in existing workflows but because we don't want too many differences with upstream \TeX Live we just follow up on that patch (which is a functional one and not really a fix). It is up to macro packages maintainers to deal with possible compatibility issues and in $\text{Lua}\TeX$ they can do so via the callbacks that deal with reading from files.

The previous behaviour was a known side effect and (as that kind of input normally comes from generated sources) it was normally dealt with by adding a comment token to the line in case the spaces and/or tabs were intentional and to be kept. We are aware of the fact that this contradicts some of our other choices but consistency with other engines and the fact that in `kpse` mode a common file io layer is used can have a side effect of breaking compatibility. We still stick to our view that at the log level we can (and might be) more incompatible. We already expose some more details.

3.4.7 Hyperlinks

There is an experimental feature that makes multi-line hyper links behave a little better, fixing some side effects that showed up in `r2l` typesetting but also can surface in `l2r`. Because this got unnoticed till 2023, and because it depends bit on how macro packages deal with hyper links, the fix is currently under parameter control:

```
\pdfvariable linking = 1
```

That way (we hope) legacy documents come out as expected, whatever those expectations are. One of the aspects dealt with concerns (unusual) left and right skips.





4 Using L^AT_EX

4.1 Initialization

4.1.1 L^AT_EX as a LUA interpreter

There are some situations that make Lua_{T_EX} behave like a standalone Lua interpreter:

- ▶ if a `--luaonly` option is given on the commandline, or
- ▶ if the executable is named `texlua` or `luatexlua`, or
- ▶ 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 command line in the positive values, just like the Lua interpreter.

Lua_{T_EX} will exit immediately after executing the specified Lua script and is, in effect, a somewhat bulky stand alone Lua interpreter with a bunch of extra preloaded libraries.

4.1.2 L^AT_EX as a LUA byte compiler

There are two situations that make Lua_{T_EX} behave like the Lua byte compiler:

- ▶ if a `--luaonly` option is given on the command line, or
- ▶ if the executable is named `texluac`

In this mode, Lua_{T_EX} is exactly like `luac` from the stand alone Lua distribution, except that it does not have the `-l` switch, and that it accepts (but ignores) the `--luaonly` switch. The current version of Lua can dump bytecode using `string.dump` so we might decide to drop this version of Lua_{T_EX}.

4.1.3 Other commandline processing

When the Lua_{T_EX} executable starts, it looks for the `--lua` command line option. If there is no `--lua` option, the command line is interpreted in a similar fashion as the other T_EX engines. Some options are accepted but have no consequence. The following command-line options are understood:

| COMMANDLINE ARGUMENT | EXPLANATION |
|---|--|
| <code>--credits</code> | display credits and exit |
| <code>--debug-format</code> | enable format debugging |
| <code>--draftmode</code> | switch on draft mode i.e. generate no output in pdf mode |
| <code>--[no-]check-dvi-total-pages</code> | exit when DVI exceeds 65535 pages (default: check) |
| <code>--[no-]file-line-error</code> | disable/enable <code>file:line:error</code> style messages |
| <code>--[no-]file-line-error-style</code> | aliases of <code>--[no-]file-line-error</code> |



| | |
|--------------------------------------|---|
| <code>--fmt=FORMAT</code> | load the format file <code>FORMAT</code> |
| <code>--halt-on-error</code> | stop processing at the first error |
| <code>--help</code> | display help and exit |
| <code>--ini</code> | be <code>iniluatex</code> , for dumping formats |
| <code>--interaction=STRING</code> | set interaction mode: <code>batchmode</code> , <code>nonstopmode</code> , <code>scrollmode</code> or <code>errorstopmode</code> |
| <code>--jobname=STRING</code> | set the job name to <code>STRING</code> |
| <code>--kpathsea-debug=NUMBER</code> | set path searching debugging flags according to the bits of <code>NUMBER</code> |
| <code>--lua=FILE</code> | load and execute a Lua initialization script |
| <code>--luadebug</code> | enable the debug library |
| <code>--[no-]mktex=FMT</code> | disable/enable <code>mktexFMT</code> generation with <code>FMT</code> is <code>tex</code> or <code>tfm</code> |
| <code>--nosocket</code> | disable the Lua socket library |
| <code>--no-socket</code> | disable the Lua socket library |
| <code>--socket</code> | enable the Lua socket library |
| <code>--output-comment=STRING</code> | use <code>STRING</code> for dvi file comment instead of date (no effect for pdf) |
| <code>--output-directory=DIR</code> | use <code>DIR</code> as the directory to write files to |
| <code>--output-format=FORMAT</code> | use <code>FORMAT</code> for job output; <code>FORMAT</code> is <code>dvi</code> or <code>pdf</code> |
| <code>--progname=STRING</code> | set the program name to <code>STRING</code> |
| <code>--recorder</code> | enable filename recorder |
| <code>--safer</code> | disable easily exploitable Lua commands |
| <code>--[no-]shell-escape</code> | disable/enable system calls |
| <code>--shell-restricted</code> | restrict system calls to a list of commands given in <code>texmf.cnf</code> |
| <code>--synctex=NUMBER</code> | enable <code>synctex</code> |
| <code>--utc</code> | use <code>utc</code> times when applicable |
| <code>--version</code> | display version and exit |

We don't support `\write 18` because `os.execute` can do the same. It simplifies the code and makes more write targets possible.

The value to use for `\jobname` is decided as follows:

- ▶ If `--jobname` is given on the command line, its argument will be the value for `\jobname`, without any changes. The argument will not be used for actual input so it need not exist. The `--jobname` switch only controls the `\jobname` setting.
- ▶ Otherwise, `\jobname` will be the name of the first file that is read from the file system, with any path components and the last extension (the part following the last `.`) stripped off.
- ▶ There is an exception to the previous point: if the command line goes into interactive mode (by starting with a command) and there are no files input via `\everyjob` either, then the `\jobname` is set to `texput` as a last resort.

The file names for output files that are generated automatically are created by attaching the proper extension (`log`, `pdf`, etc.) to the found `\jobname`. These files are created in the directory pointed to by `--output-directory`, or in the current directory, if that switch is not present. If `--output-directory` is not empty, its value it's copied to the `TEXMF_OUTPUT_DIRECTORY` env. variable; if it's empty, the value of `TEXMF_OUTPUT_DIRECTORY` is the value of the output directory.



Without the `--lua` option, command line processing works like it does in any other web2c-based typesetting engine, except that LuaTeX has a few extra switches and lacks some others. Also, if the `--lua` option is present, LuaTeX will enter an alternative mode of command line processing in comparison to the standard web2c programs. In this mode, a small series of actions is taken in the following order:

1. First, it will parse the command line as usual, but it will only interpret a small subset of the options immediately: `--safer`, `--nosocket`, `--no-socket`, `--socket`, `--[no-]shell-escape`, `--enable-writel8`, `--disable-writel8`, `--shell-restricted`, `--help`, `--version`, and `--credits`.
2. Next LuaTeX searches for the requested Lua initialization script. If it cannot be found using the actual name given on the command line, a second attempt is made by prepending the value of the environment variable `LUATEXDIR`, if that variable is defined in the environment.
3. Then it checks the various safety switches. You can use those to disable some Lua commands that can easily be abused by a malicious document. Currently `--safer` nils the following functions:

| LIBRARY | FUNCTIONS |
|---------|--|
| os | execute exec kpsepopen spawn setenv rename remove tmpdir |
| io | popen output tmpfile |
| lfs | rmdir mkdir mkdirp chdir lock touch |

Furthermore, it disables loading of compiled Lua libraries and it makes `io.open()` fail on files that are opened for anything besides reading.

Finally, it disables the socket library unconditionally (but not the `mime` library which is always available).

From version 1.18.0 and if `kpathsea` is used, with the exception of `debug.traceback` the `debug` library is not enabled by default; it can be enabled with the `--luadebug` switch. The `debug` library is always enabled in shell-escape mode.

Also from version 1.18.0 and if `kpathsea` is used, the functions `os.rename`, `os.remove`, `lfs.attributes`, `lfs.chdir`, `lfs.lock_dir`, `lfs.dir`, `lfs.link`, `lfs.mkdir`, `lfs.mkdirp`, `lfs.rmdir`, `lfs.symlinkattributes`, `lfs.touch` return true if both `kpse.in_name_ok_silent_extended` and `kpse.out_name_ok_silent_extended` validate the pathname; `lfs.attributes`, `lfs.dir` and `lfs.symlinkattributes` are validated only against `kpse.in_name_ok_silent_extended`.

4. When LuaTeX starts it sets the `locale` to a neutral value. If for some reason you use `os.setlocale`, you need to make sure you nil it afterwards because otherwise it can interfere with code that for instance generates dates. You can ignore the `locale` with:

```
os.setlocale(nil,nil)
```

The `--nosocket` or `--no-socket` option makes the socket library unavailable, so that Lua cannot use networking; `--socket` option makes the socket library available.

The switches `--[no-]shell-escape`, `--[enable|disable]-writel8`, and `--shell-restricted` have the same effects as in pdfTeX, and additionally make `io.popen()`, `os.execute`, `os.exec`, `os.kpsepopen` and `os.spawn` adhere to the requested option.



By default the socket library is not enabled: one can enable it with `--socket` or with `--shell-escape` (but without `--shell-restricted`) and disable it with `--nosocket` (or `--no-socket`) or unconditionally with `--safer`.

In case of conflictual options, the most restrictive wins.

The mime library is always available.

5. Next the initialization script is loaded and executed. From within the script, the entire command line is available in the Lua table `arg`, beginning with `arg[0]`, containing the name of the executable. As consequence warnings about unrecognized options are suppressed.

Command line processing happens very early on. So early, in fact, that none of $\text{T}_{\text{E}}\text{X}$'s initializations have taken place yet. For that reason, the tables that deal with typesetting, like `tex`, `token`, `node` and `pdf`, are off-limits during the execution of the startup file (they are `nil`'d). 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 $\text{T}_{\text{E}}\text{X}$ does not even know its `\jobname` yet at this point).

Everything you do in the Lua initialization script will remain visible during the rest of the run, with the exception of the $\text{T}_{\text{E}}\text{X}$ specific libraries like `tex`, `token`, `node` and `pdf` tables. These 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 $\text{T}_{\text{E}}\text{X}$ -independent initializations (if you need any), to parse the command line, set values in the `texconfig` table, and register the callbacks you need.

Lua $\text{T}_{\text{E}}\text{X}$ allows some of the command line options to be overridden by reading values 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 Lua $\text{T}_{\text{E}}\text{X}$ not to initialize `kpathsea` at all (set `texconfig.kpse_init` to `false` for that), Lua $\text{T}_{\text{E}}\text{X}$ acts on some more command line options after the initialization script is finished: in order to initialize the built-in `kpathsea` library properly, Lua $\text{T}_{\text{E}}\text{X}$ needs to know the correct program name to use, and for that it needs to check `--progname`, or `--ini` and `--fmt`, if `--progname` is missing.

From version 1.17.1, in `dvi` mode the new commandline switch `--check-dvi-total-pages`, enabled by default, checks that the total number of pages does not exceeds 65535, and in case the run abort. This breaks the compatibility with `pdf $\text{T}_{\text{E}}\text{X}$` where, as in $\text{T}_{\text{E}}\text{X}$, when the total number of pages is greater than 65535 the file will lie. The previous behaviour can be restored with `--[no-]check-dvi-total-pages`.

4.2 LUA behaviour

4.2.1 The LUA version

We currently use Lua 5.3 and will follow developments of the language but normally with some delay. Therefore the user needs to keep an eye on (subtle) differences in successive versions of



the language. Also, LuaJIT_{TeX} lags behind in the sense that LuaJIT is not in sync with regular Lua development. Here is an example of one aspect.

Lua's `tostring` function (and `string.format` may return values in scientific notation, thereby confusing the _{TeX} end of things when it is used as the right-hand side of an assignment to a `\dimen` or `\count`. The output of these serializers also depend on the Lua version, so in Lua 5.3 you can get different output than from 5.2.

4.2.2 Integration in the TDS ecosystem

The main _{TeX} distributions follow the _{TeX} directory structure (tds). Lua_{TeX} is able to use the `kpathsea` library to find `require()`d modules. For this purpose, `package.searchers[2]` is replaced by a different loader function, that decides at runtime whether to use `kpathsea` or the built-in core Lua function. It uses `kpathsea` when that is already initialized at that point in time, otherwise it reverts to using the normal `package.path` loader.

Initialization of `kpathsea` can happen either implicitly (when Lua_{TeX} starts up and the startup script has not set `texconfig.kpse_init` to false), or explicitly by calling the Lua function `kpse.set_program_name()`.

4.2.3 Loading libraries

Lua_{TeX} is able to use dynamically loadable Lua libraries, unless `--safer` was given as an option on the command line. For this purpose, `package.searchers[3]` is replaced by a different loader function, that decides at runtime whether to use `kpathsea` or the built-in core Lua function. It uses `kpathsea` when that is already initialized at that point in time, otherwise it reverts to using the normal `package.cpath` loader.

This functionality required an extension to `kpathsea`. There is a new `kpathsea` file format: `kpse_clua_format` that searches for files with extension `.dll` and `.so`. The `texmf.cnf` setting for this variable is `CLUAINPUTS`, and by default it has this value:

```
CLUAINPUTS=.:$SELFAUTOLOC/lib/{$progname,$engine,}/lua//
```

This path is imperfect (it requires a tds subtree below the binaries directory), but the architecture has to be in the path somewhere, and the currently simplest way to do that is to search below the binaries directory only. Of course it no big deal to write an alternative loader and use that in a macro package. One level up (a `lib` directory parallel to `bin`) would have been nicer, but that is not doable because _{TeX}Live uses a `bin/<arch>` structure.

Loading dynamic Lua libraries will fail if there are two Lua libraries loaded at the same time (which will typically happen on win32, because there is one Lua 5.3 inside Lua_{TeX}, and another will likely be linked to the `dll` file of the module itself).

4.2.4 Executing programs

In keeping with the other _{TeX}-like programs in _{TeX}Live, the Lua functions `os.execute`, `os.kpse-popen` and `io.popen`, as well as the two new functions `os.exec` and `os.spawn` that are explained below, take the value of `shell_escape` and/or `shell_escape_commands` in account. Whenever



LuaTeX is run with the assumed intention to typeset a document (and by that we mean that it is called as `luatex`, as opposed to `texlua`, and that the command line option `--luaonly` was not given), it will only run the four functions above if the matching `texmf.cnf` variable(s) or their `texconfig` (see section 10.4) counterparts allow execution of the requested system command. In ‘script interpreter’ runs of LuaTeX, these settings have no effect, and all four functions have their original meaning.

Some libraries have a few more functions, either coded in C or in Lua. For instance, when we started with LuaTeX we added some helpers to the `luafilesystem` namespace `lfs`. The two boolean functions `lfs.isdir` and `lfs.isfile` were speedy and better variants of what could be done with `lfs.attributes`. The additional function `lfs.shortname` takes a file name and returns its short name on win32 platforms; `lfs.mkdirp` is like `lfs.mkdir` but make parent directories as needed. Finally, for non-win32 platforms only, we provided `lfs.readlink` that takes an existing symbolic link as argument and returns its name. However, the `lfs` library evolved so we have dropped these in favour of pure Lua variants. The `shortname` helper is obsolete and now just returns the name.

4.2.5 Multibyte string functions

The `string` library has a few extra functions, for example `string.explode`. This function takes upto two arguments: `string.explode(s[,m])` and returns an array containing the string argument `s` split into sub-strings 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 sub-strings). 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`, `string.utfcharacters`, `string.characters`, `string.characterpairs`, `string.bytes` and `string.bytepairs`.

- ▶ `string.utfvalues(s)`: an integer value in the Unicode range
- ▶ `string.utfcharacters(s)`: 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 or an empty second string if the string length was odd
- ▶ `string.bytes(s)`: a single byte value
- ▶ `string.bytepairs(s)`: two byte values or nil instead of a number as its second return value if the string length was odd

The `string.characterpairs()` and `string.bytepairs()` iterators are useful especially in the conversion of utf16 encoded data into utf8.

There is also a two-argument form of `string.dump()`. The second argument is a boolean which, if true, strips the symbols from the dumped data. This matches an extension made in `luajit`. This is typically a function that gets adapted as Lua itself progresses.

The `string` library functions `len`, `lower`, `sub` etc. are not Unicode-aware. For strings in the utf8 encoding, i.e., strings containing characters above code point 127, the corresponding func-



tions from the `slnunicode` library can be used, e.g., `unicode.utf8.len`, `unicode.utf8.lower` etc. The exceptions are `unicode.utf8.find`, that always returns byte positions in a string, and `unicode.utf8.match` and `unicode.utf8.gmatch`. While the latter two functions in general *are* Unicode-aware, they fall-back to non-Unicode-aware behavior when using the empty capture `()` but other captures work as expected. For the interpretation of character classes in `unicode.utf8` functions refer to the library sources at <http://luaforge.net/projects/sln>.

Version 5.3 of Lua provides some native utf8 support but we have added a few similar helpers too: `string.utfvalue`, `string.utfcharacter` and `string.utflength`.

- ▶ `string.utfvalue(s)`: returns the codepoints of the characters in the given string
- ▶ `string.utfcharacter(c, ...)`: returns a string with the characters of the given code points
- ▶ `string.utflength(s)`: returns the length of the given string

These three functions are relative fast and don't do much checking. They can be used as building blocks for other helpers.

4.2.6 Extra os library functions

The `os` library has a few extra functions and variables: `os.selfdir`, `os.exec`, `os.kpsopen`, `os.socketgettime`, `os.socketsleep`, `os.spawn`, `os.setenv`, `os.env`, `os.gettimeofday`, `os.times`, `os.sleep`, `os.tmpdir`, `os.type`, `os.name` and `os.uname`, that we will discuss here.

- ▶ `os.selfdir` is a variable that holds the directory path of the actual executable. For example: `\directlua{tex.sprint(os.selfdir)}`.
- ▶ `os.exec(commandline)` is a variation on `os.execute`. Here `commandline` can be either a single string or a single table.
 - If the argument is a table LuaTeX first checks if there is a value at integer index zero. If there is, this is the command to be executed. Otherwise, it will use the value at integer index one. If neither are present, nothing at all happens.
 - The set of consecutive values starting at integer 1 in the table are the arguments that are passed on to the command (the value at index 1 becomes `arg[0]`). The command is searched for in the execution path, so there is normally no need to pass on a fully qualified path name.
 - If the argument is a string, then it is automatically converted into a table by splitting on whitespace. In this case, it is impossible for the command and first argument to differ from each other.
 - In the string argument format, whitespace can be protected by putting (part of) an argument inside single or double quotes. One layer of quotes is interpreted by LuaTeX, and all occurrences of `\`, `'` or `\\` within the quoted text are unescaped. In the table format, there is no string handling taking place.

This function normally does not return control back to the Lua script: the command will replace the current process. However, it will return the two values `nil` and `error` if there was a problem while attempting to execute the command.

On MS Windows, the current process is actually kept in memory until after the execution of the command has finished. This prevents crashes in situations where TeX Lua scripts are run inside integrated TeX environments.



The original reason for this command is that it cleans out the current process before starting the new one, making it especially useful for use in $\text{T}_{\text{E}}\text{X}$ Lua.

- ▶ `os.kpseopen(commandline, [opt])` is similar to `io.popen` but with a preliminary check of the commandline; if the check is ok then the return value is the same as in `io.popen`; Otherwise it will return the two values `nil` and `error`.
- ▶ `os.socketgettime` and `os.socketsleep` are the same as for `socket.gettime` and `socket.sleep` but they are always available.
- ▶ `os.spawn(commandline)` is a returning version of `os.exec`, with otherwise identical calling conventions.

If the command ran ok, then the return value is the exit status of the command. Otherwise, it will return the two values `nil` and `error`.

`os.spawn()` takes an optional second argument, a table of key-value pairs for the environment of the spawned process. Note that if you do pass this table, it will be used as the *complete* environment for the spawned process, so you'll likely want to start from `os.env` and add or remove keys as needed.

- ▶ `os.setenv(key, value)` sets a variable in the environment. Passing `nil` instead of a value string will remove the variable.
 - ▶ `os.env` 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 according to the Unix C library function 'times'. This function is not available on the MS Windows and SunOS platforms, so do not use this function for portable documents.
 - ▶ `os.sleep(interval[, unit])` suspends the execution of the current run for a given number of seconds. If the optional argument `unit` is present, the function waits `interval / units` seconds. `os.sleep(1, 1000)` for example pauses the program for one millisecond.
 - ▶ `os.tmpdir([template])` creates a directory in the 'current directory' with the name `lua-tex.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. You can also use your own `template` for the name of the temporary folder. However, the passed string must end with six capital X-es. For example, the template `tmp.XXXXXX` could result in the folder name `tmp.vX3gPo`.
 - ▶ `os.type` is a string that gives a global indication of the class of operating system. The possible values are currently `windows`, `unix`, and `msdos` (you are unlikely to find this value 'in the wild').
 - ▶ `os.name` is a string that gives a more precise indication of the operating system. These possible values are not yet fixed, and for `os.type` values `windows` and `msdos`, the `os.name` values are simply `windows` and `msdos`
- The list for the type `unix` is more precise: `linux`, `freebsd`, `kfreebsd`, `cygwin`, `openbsd`, `solaris`, `sunos` (pre-solaris), `hpux`, `irix`, `macosx`, `gnu` (`hurd`), `bsd` (unknown, but `bsd-like`), `sysv` (unknown, but `sysv-like`), `generic` (unknown).
- ▶ `os.uname` returns a table with specific operating system information acquired at runtime. The keys in the returned table are all string values, and their names are: `sysname`, `machine`, `release`, `version`, and `nodename`.



4.2.7 Binary input from files with `fio`

There is a whole set of helpers for reading numbers and strings from a file: `fio.readcardinal1`, `fio.readcardinal2`, `fio.readcardinal3`, `fio.readcardinal4`, `fio.readcardinaltable`, `fio.readinteger1`, `fio.readinteger2`, `fio.readinteger3`, `fio.readinteger4`, `fio.readintegertable`, `fio.readfixed2`, `fio.readfixed4`, `fio.read2dot14`, `fio.setposition`, `fio.getposition`, `fio.skipposition`, `fio.readbytes`, `fio.readbytetable`. They work on normal Lua file handles.

This library provides a set of functions for reading numbers from a file and in addition to the regular `io` library functions.

| | |
|---------------------------------------|-------------------------------------|
| <code>readcardinal1(f)</code> | a 1 byte unsigned integer |
| <code>readcardinal2(f)</code> | a 2 byte unsigned integer |
| <code>readcardinal3(f)</code> | a 3 byte unsigned integer |
| <code>readcardinal4(f)</code> | a 4 byte unsigned integer |
| <code>readcardinaltable(f,n,b)</code> | n cardinals of b bytes |
| <code>readinteger1(f)</code> | a 1 byte signed integer |
| <code>readinteger2(f)</code> | a 2 byte signed integer |
| <code>readinteger3(f)</code> | a 3 byte signed integer |
| <code>readinteger4(f)</code> | a 4 byte signed integer |
| <code>readintegertable(f,n,b)</code> | n integers of b bytes |
| <code>readfixed2(f)</code> | a 2 byte float (used in font files) |
| <code>readfixed4(f)</code> | a 4 byte float (used in font files) |
| <code>read2dot14(f)</code> | a 2 byte float (used in font files) |
| <code>setposition(f,p)</code> | goto position p |
| <code>getposition(f)</code> | get the current position |
| <code>skipposition(f,n)</code> | skip n positions |
| <code>readbytes(f,n)</code> | n bytes |
| <code>readbytetable(f,n)</code> | n bytes |

There are eight additional little endian variants for the `cardinal[1-4]` and `integer[1-4]` readers: `cardinal[1-4]le` and `integer[1-4]le`.

4.2.8 Binary input from strings with `sio`

A similar set of function as in the `fio` library is available in the `sio` library: `sio.readcardinal1`, `sio.readcardinal2`, `sio.readcardinal3`, `sio.readcardinal4`, `sio.readcardinaltable`, `sio.readinteger1`, `sio.readinteger2`, `sio.readinteger3`, `sio.readinteger4`, `sio.readintegertable`, `sio.readfixed2`, `sio.readfixed4`, `sio.read2dot14`, `sio.setposition`, `sio.getposition`, `sio.skipposition`, `sio.readbytes` and `sio.readbytetable`. Here the first argument is a string instead of a file handle. More details can be found in the previous section.

4.2.9 Hashes conform sha2

This library is a side effect of the `pdfc` library that needs such helpers. The `sha2.digest256`, `sha2.digest384` and `sha2.digest512` functions accept a string and return a string with the hash.



4.2.10 Locales

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

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

4.3 LUA modules

Some modules that are normally external to Lua are statically linked in with Lua_{T_EX}, because they offer useful functionality:

- ▶ `lpeg`, by Roberto Ierusalimschy, <http://www.inf.puc-rio.br/~roberto/lpeg/lpeg.html>. This library is not Unicode-aware, but interprets strings on a byte-per-byte basis. This mainly means that `lpeg.S` cannot be used with utf8 characters encoded in more than 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 multibyte characters. Therefore `lpeg.R('ä')` results in the message `bad argument #1 to 'R' (range must have two characters)`, since to `lpeg`, `ä` is two 'characters' (bytes), so `ä` totals three. In practice this is no real issue and with some care you can deal with Unicode just fine.
- ▶ `slnunicode`, from the `selene` libraries, <http://luaforge.net/projects/sln>. This library has been slightly extended so that the `unicode.utf8.*` functions also accept the first 256 values of plane 18. This is the range Lua_{T_EX} uses for raw binary output, as explained above. We have no plans to provide more like this because you can basically do all that you want in Lua.
- ▶ `luazip`, from the kepler project, <http://www.keplerproject.org/luazip/>.
- ▶ `luafilesystem`, also from the kepler project, <http://www.keplerproject.org/luafilesystem/>.
- ▶ `lzlib`, by Tiago Dionizio, <http://luaforge.net/projects/lzlib/>.
- ▶ `md5`, by Roberto Ierusalimschy <http://www.inf.puc-rio.br/~roberto/md5/md5-5/md5.html>.
- ▶ `luasocket`, by Diego Nehab <http://w3.impa.br/~diego/software/luasocket/>. The `.lua` support modules from `luasocket` are also preloaded inside the executable, there are no external file dependencies.

4.4 Testing

For development reasons you can influence the used startup date and time. This can be done in two ways.

1. By setting the environment variable `SOURCE_DATE_EPOCH`. This will influence the `TEX` parameters `time` and `date`, the random seed, the pdf timestamp and the pdf id that is derived from the time as well. This variable is consulted when the `kpse` library is enabled. Resolving is delegated to this library.
2. By setting the `start_time` variable in the `texconfig` table; as with other variables we use the internal name there. For compatibility reasons we also honour a `SOURCE_DATE_EPOCH` entry.



It should be noted that there are no such variables in other engines and this method is only relevant in case the while setup happens in Lua.

When Universal Time is needed, you can pass the flag `utc` to the engine. This property also works when the date and time are set by LuaTeX itself. It has a complementary entry `use_utc_time` in the `texconfig` table.

There is some control possible, for instance prevent filename to be written to the pdf file. This is discussed elsewhere. In ConTeXt we provide the command line argument `--nodates` that does a bit more disabling of dates.





5 Languages, characters, fonts and glyphs

5.1 Introduction

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. This packaging is needed because we may want to get the effective width of for instance a horizontal box.

When it becomes necessary to hyphenate words in a paragraph, TeX converts (one word at time) the char node records into a string 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. Keep in mind that the paragraph may contain unboxed horizontal material, which then already contains ligatures and kerns and the words therein are part of the hyphenation process.

Those char node records are somewhat misnamed, as they are glyph positions in specific fonts, and therefore not really 'characters' in the linguistic sense. There is no language information inside the char node records at all. Instead, language information is passed along using language whatsit nodes 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. It only stores the index of the current font and a reference to a character in that font.

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.

5.2 Characters, glyphs and discretionaries

TeX82 (including pdfTeX) differentiates between char nodes and lig nodes. The former are simple items that contained nothing but a 'character' and a 'font' field, and they lived in the same memory as tokens did. 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 there are a few more, like 'attr' that we will see in section 8.2.12, these nodes also contain a subtype, that codes four main types and two additional ghost types. For ligatures, multiple bits can be set at the same time (in case of a single-glyph word).

- ▶ character, for characters to be hyphenated: the lowest bit (bit 0) is set to 1.
- ▶ glyph, for specific font glyphs: the lowest bit (bit 0) is not set.
- ▶ ligature, for constructed ligatures bit 1 is set.
- ▶ ghost, for so called 'ghost objects' bit 2 is set.
- ▶ left, for ligatures created from a left word boundary and for ghosts created from `\leftghost` bit 3 gets set.
- ▶ right, for ligatures created from a right word boundary and for ghosts created from `\rightghost` bit 4 is set.

The glyph nodes 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 16383 separate languages, and words can be 256 characters long. The language is stored with each character. You can set `\firstvalidlanguage` to for instance 1 and make thereby language 0 an ignored hyphenation language.

The new primitive `\hyphenationmin` can be used to signal the minimal length of a word. This value is stored with the (current) language.

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 dependency 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.

In traditional TeX the process of hyphenation is driven by `\lccodes`. In LuaTeX we made this dependency less strong. There are several strategies possible. When you do nothing, the currently used `\lccodes` are used, when loading patterns, setting exceptions or hyphenating a list.

When you set `\savingshyphcodes` to a value greater than zero the current set of `\lccodes` will be saved with the language. In that case changing a `\lccode` afterwards has no effect. However, you can adapt the set with:

```
\hjcode`a=`a
```

This change is global which makes sense if you keep in mind that the moment that hyphenation happens is (normally) when the paragraph or a horizontal box is constructed. When `\savingshyphcodes` was zero when the language got initialized you start out with nothing, otherwise you already have a set.

When a `\hjcode` is greater than 0 but less than 32 it indicates the to be used length. In the following example we map a character (x) onto another one in the patterns and tell the engine that æ



counts as one character. Because traditionally zero itself is reserved for inhibiting hyphenation, a value of 32 counts as zero.

Here are some examples (we assume that French patterns are used):

```

                                foobar  foo-bar
\hjcode `x=`o                   fxxbar  fxx-bar
\lefthyphenmin 3                 ædipus  ædi-pus
\lefthyphenmin 4                 ædipus  ædipus
\hjcode `æ=2                     ædipus  ædi-pus
\hjcode `i=32 \hjcode `d=32     ædipus  ædipus
```

Carrying all this information with each glyph would give too much overhead and also make the process of setting up these codes more complex. A solution with `hjcode` sets was considered but rejected because in practice the current approach is sufficient and it would not be compatible anyway.

Beware: the values are always saved in the format, independent of the setting of `\savingshyphcodes` at the moment the format is dumped.

A boundary node normally would mark the end of a word which interferes with for instance discretionary injection. For this you can use the `\wordboundary` as a trigger. Here are a few examples of usage:

```
discrete---discrete
```

```
    discrete—discrete
```

```
discrete\discretionary{}{}{---}discrete
```

```
    discrete
    discrete
```

```
discrete\wordboundary\discretionary{}{}{---}discrete
```

```
    dis-
    crete
    discrete
```

```
discrete\wordboundary\discretionary{}{}{---}\wordboundary discrete
```

```
    dis-
    crete
    dis-
    crete
```

```
discrete\wordboundary\discretionary{---}{}{} \wordboundary discrete
```

```
    dis-
    crete—
    dis-
    crete
```



We only accept an explicit hyphen when there is a preceding glyph and we skip a sequence of explicit hyphens since that normally indicates a -- or --- ligature in which case we can in a worse case usage get bad node lists later on due to messed up ligature building as these dashes are ligatures in base fonts. This is a side effect of separating the hyphenation, ligaturing and kerning steps.

The start and end of a sequence of characters is signalled by a glue, penalty, kern or boundary node. But by default also a hlist, vlist, rule, dir, whatsit, ins, and adjust node indicate a start or end. You can omit the last set from the test by setting \hyphenationbounds to a non-zero value:

| VALUE | BEHAVIOUR |
|-------|-----------------------------|
| 0 | not strict |
| 1 | strict start |
| 2 | strict end |
| 3 | strict start and strict end |

The word start is determined as follows:

| NODE | BEHAVIOUR |
|------------------|---|
| boundary | yes when wordboundary |
| hlist | when hyphenationbounds 1 or 3 |
| vlist | when hyphenationbounds 1 or 3 |
| rule | when hyphenationbounds 1 or 3 |
| dir | when hyphenationbounds 1 or 3 |
| whatsit | when hyphenationbounds 1 or 3 |
| glue | yes |
| math | skipped |
| glyph | exhyphenchar (one only) : yes (so no - —) |
| otherwise | yes |

The word end is determined as follows:

| NODE | BEHAVIOUR |
|-----------------|--|
| boundary | yes |
| glyph | yes when different language |
| glue | yes |
| penalty | yes |
| kern | yes when not italic (for some historic reason) |
| hlist | when hyphenationbounds 2 or 3 |
| vlist | when hyphenationbounds 2 or 3 |
| rule | when hyphenationbounds 2 or 3 |
| dir | when hyphenationbounds 2 or 3 |
| whatsit | when hyphenationbounds 2 or 3 |
| ins | when hyphenationbounds 2 or 3 |
| adjust | when hyphenationbounds 2 or 3 |

Figures 5.1 upto 5.5 show some examples. In all cases we set the min values to 1 and make sure that the words hyphenate at each character.



| | | | |
|----|----|----|----|
| o- | o- | o- | o- |
| n- | n- | n- | n- |
| e | e | e | e |
| 0 | 1 | 2 | 3 |

Figure 5.1 one

| | | | |
|-----|------|-------|--------|
| o- | o- | onet- | onetwo |
| n- | n- | w- | |
| et- | etwo | o | |
| w- | | | |
| o | | | |
| 0 | 1 | 2 | 3 |

Figure 5.2 one\null two

| | | | |
|-----|------|-------|--------|
| o- | o- | onet- | onetwo |
| n- | n- | w- | |
| et- | etwo | o | |
| w- | | | |
| o | | | |
| 0 | 1 | 2 | 3 |

Figure 5.3 \null one\null two

| | | | |
|-----|------|--------|--------|
| o- | o- | onetwo | onetwo |
| n- | n- | | |
| et- | etwo | | |
| w- | | | |
| o | | | |
| 0 | 1 | 2 | 3 |

Figure 5.4 one\null two\null

In traditional T_EX ligature building and hyphenation are interwoven with the line break mechanism. In LuaT_EX these phases are isolated. As a consequence we deal differently with (a sequence of) explicit hyphens. We already have added some control over aspects of the hyphenation and yet another one concerns automatic hyphens (e.g. - characters in the input).

When `\automatichyphenmode` has a value of 0, a hyphen will be turned into an automatic discretionary. The snippets before and after it will not be hyphenated. A side effect is that a leading hyphen can lead to a split but one will seldom run into that situation. Setting a pre and post character makes this more prominent. A value of 1 will prevent this side effect and a value of 2 will not turn the hyphen into a discretionary. Experiments with other options, like permitting hyphenation of the words on both sides were discarded.

In figure 5.6 and 5.7 we show what happens with three samples:

Input A:

```
before-after \par
before--after \par
```



| | | | |
|----------------------------|------------------|--------|--------|
| o- n- et- w- o | o- n- etwo | onetwo | onetwo |
| 0 | 1 | 2 | 3 |

Figure 5.5 \null one\null two\null

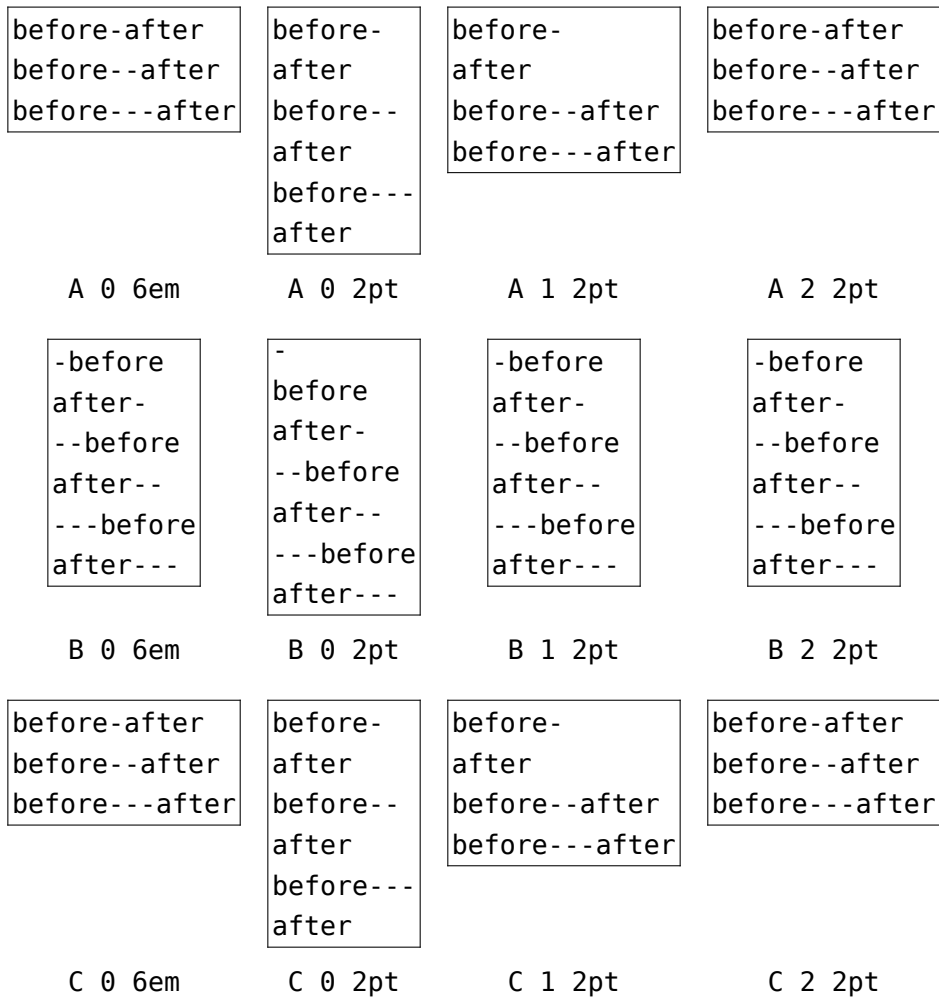


Figure 5.6 The automatic modes 0 (default), 1 and 2, with a \hsize of 6em and 2pt (which triggers a linebreak).

before---after \par

Input B:

```
-before \par
after- \par
--before \par
after-- \par
---before \par
after---
```



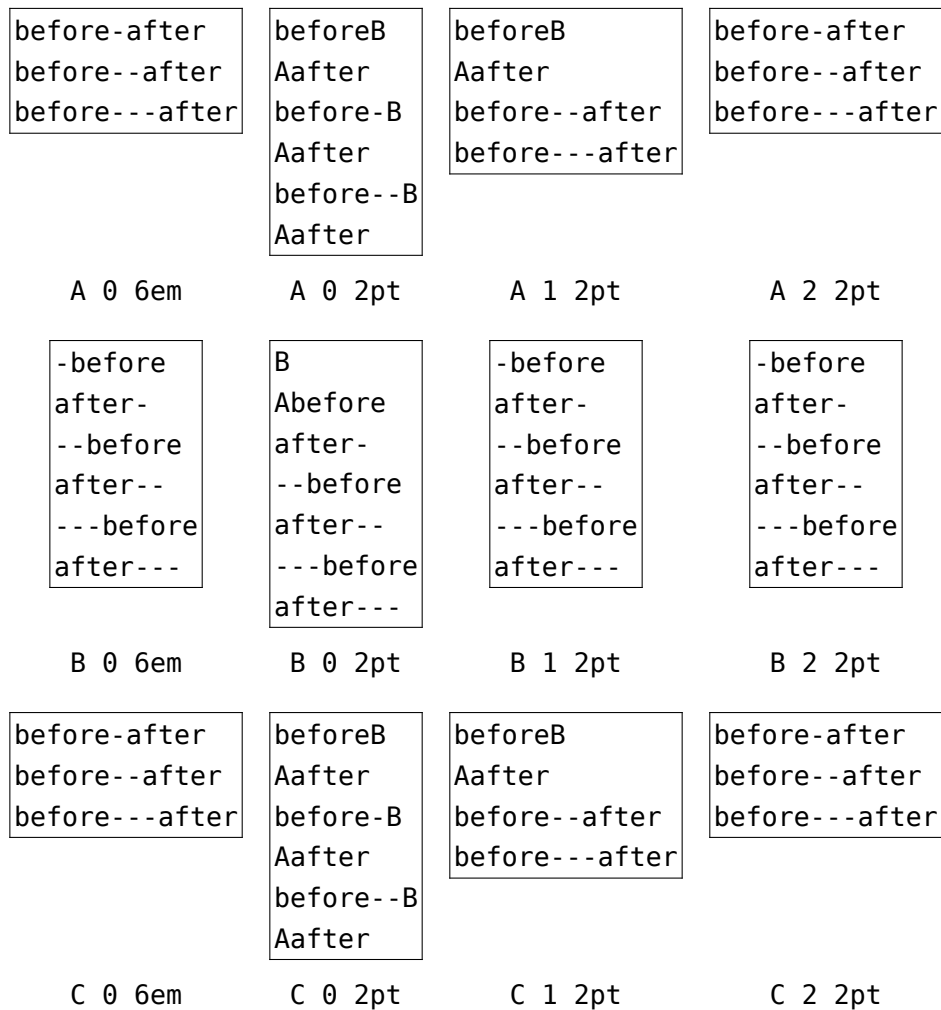


Figure 5.7 The automatic modes 0 (default), 1 and 2, with `\preexhyphenchar` and `\postexhyphenchar` set to characters A and B.

Input C:

```
before-after \par
before--after \par
before---after \par
```

As with primitive companions of other single character commands, the `\-` command has a more verbose primitive version in `\explicitdiscretionary` and the normally intercepted in the hyphenator character `-` (or whatever is configured) is available as `\automaticdiscretionary`.

5.3 The main control loop

In Lua_T_EX'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 exceptions.

1. The `\accent` primitive 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 T_EX82 is explicitly dependent 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 T_EX82, `\accent` prohibits hyphenation of the current word. Since in LuaT_EX hyphenation only takes place on 'character' nodes, it is possible to achieve the same effect. Of course, modern Unicode aware macro packages will not use the `\accent` primitive at all but try to map directly on composed characters.

This change of meaning did happen with `\char`, that now generates 'glyph' nodes with a character subtype. In traditional T_EX there was a strong relationship between the 8-bit input encoding, hyphenation and glyphs taken from a font. In LuaT_EX we have utf input, and in most cases this maps directly to a character in a font, apart from glyph replacement in the font engine. If you want to access arbitrary glyphs in a font directly you can always use Lua to do so, because fonts are available as Lua table.

2. All the results of processing in math mode eventually become nodes with 'glyph' subtypes. In fact, the result of processing math is just a regular list of glyphs, kerns, glue, penalties, boxes etc.
3. 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.
4. Automatic discretionary are handled differently. T_EX82 inserts an empty discretionary after sensing an input character that matches the `\hyphenchar` in the current font. This test is wrong in our opinion: whether or not hyphenation takes place should not depend on the current font, it is a language property.¹

In LuaT_EX, it works like this: if LuaT_EX senses a string of input characters that matches the value of the new integer parameter `\exhyphenchar`, it will insert an explicit discretionary after that series of nodes. Initially T_EX sets the `\exhyphenchar=-1`. 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 insertion of discretionaries after a sequence of explicit hyphens happens at the same time as the other Lua hyphenation processing, *not* inside the main control loop.

The only use LuaT_EX has for `\hyphenchar` is at the check whether a word should be considered for hyphenation at all. If the `\hyphenchar` of the font attached to the first character node in a word is negative, then hyphenation of that word is abandoned immediately. This behaviour is added for backward compatibility only, and the use of `\hyphenchar=-1` as a means of preventing hyphenation should not be used in new LuaT_EX documents.

5. The `\setlanguage` command 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`.
6. The `\noboundary` command (that prohibits word boundary processing where that would normally take place) now does create nodes. These nodes 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.
7. There is no longer a `main_loop` label in the code. Remember that T_EX82 did quite a lot of processing while adding `char_nodes` to the horizontal list? For speed reasons, it handled

¹ When T_EX showed up we didn't have Unicode yet and being limited to eight bits meant that one sometimes had to compromise between supporting character input, glyph rendering, hyphenation.



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.

Because we tend to make hard coded behaviour configurable a few new primitives have been added:

```
\hyphenpenaltymode
\automatichyphenpenalty
\explicitlyhyphenpenalty
```

The first parameter has the following consequences for automatic discs (the ones resulting from an `\exhyphenchar`):

| MODE | AUTOMATIC DISC - | EXPLICIT DISC \- |
|------|--------------------------------------|---------------------------------------|
| 0 | <code>\exhyphenpenalty</code> | <code>\exhyphenpenalty</code> |
| 1 | <code>\hyphenpenalty</code> | <code>\hyphenpenalty</code> |
| 2 | <code>\exhyphenpenalty</code> | <code>\hyphenpenalty</code> |
| 3 | <code>\hyphenpenalty</code> | <code>\exhyphenpenalty</code> |
| 4 | <code>\automatichyphenpenalty</code> | <code>\explicitlyhyphenpenalty</code> |
| 5 | <code>\exhyphenpenalty</code> | <code>\explicitlyhyphenpenalty</code> |
| 6 | <code>\hyphenpenalty</code> | <code>\explicitlyhyphenpenalty</code> |
| 7 | <code>\automatichyphenpenalty</code> | <code>\exhyphenpenalty</code> |
| 8 | <code>\automatichyphenpenalty</code> | <code>\hyphenpenalty</code> |

other values do what we always did in LuaTeX: insert `\exhyphenpenalty`.

5.4 Loading patterns and exceptions

Although we keep the traditional approach towards hyphenation (which is still superior) the implementation of the hyphenation algorithm in LuaTeX is quite different from the one in TeX82.

After expansion, the argument for `\patterns` has to be proper utf8 with individual patterns separated by spaces, no `\char` or `\chardef` commands are allowed. The current implementation is quite strict and will reject all non-Unicode characters. Likewise, the expanded argument for `\hyphenation` also has to be proper utf8, but here a bit of extra syntax is provided:

1. Three sets of arguments in curly braces (`{ } { } { }`) indicate a desired complex discretionary, with arguments as in `\discretionary`’s command in normal document input.
2. A `-` 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 to deal with `\relax` commands that may sneak in.
4. An `=` indicates a (non-discretionary) hyphen in the document input.

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 Lua \TeX 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.

It is possible to specify extra hyphenation points in compound words by using `{-}{-}{-}` for the explicit hyphen character (replace `-` by the actual explicit hyphen character if needed). For example, this matches the word ‘multi-word-boundaries’ and allows an extra break inbetween ‘boun’ and ‘daries’:

```
\hyphenation{multi{-}{-}{-}word{-}{-}{-}boun-daries}
```

The motivation behind the ε - \TeX extension `\savingshyphcodes` was that hyphenation heavily depended on font encodings. This is no longer true in Lua \TeX , and the corresponding primitive is basically ignored. Because we now have `\hjcode`, the case relate codes can be used exclusively for `\uppercase` and `\lowercase`.

The three curly brace pair pattern in an exception can be somewhat unexpected so we will try to explain it by example. The pattern `foo{}{}{x}bar` pattern creates a lookup `fooxbar` and the pattern `foo{}{}{}bar` creates `foobar`. Then, when a hit happens there is a replacement text (x) or none. Because we introduced penalties in discretionary nodes, the exception syntax now also can take a penalty specification. The value between square brackets is a multiplier for `\exceptionpenalty`. Here we have set it to 10000 so effectively we get 30000 in the example.

| x{a-}{-b}{-}x{a-}{-b}{-}x{a-}{-b}{-}x{a-}{-b}{-}xx | | | |
|--|--|--|--|
| 10em | 3em | 0em | 6em |
| 123 xxxxxx 123 | 123 xxa- -bxa- -bxa- -bxx 123 | 123 xa- -bxa- -bxa- -bxa- -bxx 123 | 123 xxxxxx xxxxxx xxa- -bxxxx xxa- -bxxxx 123 |



| x{a-}{-b}{x}{a-}{-b}{[3]x}{a-}{-b}{[1]x}{a-}{-b}{xx | | | |
|---|--------------------------------------|--------------------------------------|--|
| 10em | 3em | 0em | 6em |
| 123 xxxxxx 123 | 123 xa- -bxxxa- -bxx 123 | 123 xa- -bxxxa- -bxx 123 | 123 xxxxa- -bxx xxxxxx xxxxxx xa- -bxxxxx 123 |

| z{a-}{-b}{z}{a-}{-b}{z}{a-}{-b}{z}{a-}{-b}{z}z | | | |
|--|------------------------------------|--|--|
| 10em | 3em | 0em | 6em |
| 123 zzzzzz 123 | 123 zza- -ba- -bzz 123 | 123 za- -ba- -ba- -ba- -bz 123 | 123 zzzzzz zzzzzz zzza- -bzz zzzzzz 123 |

| z{a-}{-b}{z}{a-}{-b}{z}[3]{a-}{-b}{z}[1]{a-}{-b}{z}z | | | |
|--|------------------------------------|------------------------------------|--|
| 10em | 3em | 0em | 6em |
| 123 zzzzzz 123 | 123 za- -bzza- -bz 123 | 123 za- -bzza- -bz 123 | 123 zzzza- -bz zzzzzz zzzzzz za- -bzzzz 123 |

5.5 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 noticeable differences in handling as well.

First and foremost, there is no ‘compressed trie’ involved in hyphenation. The algorithm still reads pattern files generated by Patgen, but LuaTeX uses a finite state hash to match the patterns against the word to be hyphenated. This algorithm is based on the ‘libhjn’ library used by OpenOffice, which in turn is inspired by TeX.

There are a few differences between LuaTeX and TeX82 that are a direct result of the implementation:

- ▶ 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 implicit discretionary nodes, instead of TeX82's `\hyphenchar`, and the values of the language-specific variables `\preexhyphenchar` and `\postexhyphenchar` for explicit discretionary nodes (instead of TeX82's empty discretionary).
- ▶ The value of the two counters related to hyphenation, `\hyphenpenalty` and `\exhyphenpenalty`, are now stored in the discretionary nodes. This permits a local overload for explicit `\discretionary` commands. The value current when the hyphenation pass is applied is used. When no callbacks are used this is compatible with traditional TeX. When you apply the Lua `lang.hyphenate` function the current values are used.
- ▶ The hyphenation exception dictionary is maintained as key-value hash, and that is also dynamic, so the `hyph_size` setting is not used either.

Because we store penalties in the disc node the `\discretionary` command has been extended to accept an optional penalty specification, so you can do the following:

```
\hsizelmm
1:foo{\hyphenpenalty 10000\discretionary{}{}{}}bar\par
2:foo\discretionary penalty 10000 {}{}{}}bar\par
3:foo\discretionary{}{}{}}bar\par
```

This results in:

```
1:foobar
2:foobar
3:foo
bar
```

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=-`, `\posthyphenchar=0`, `\preexhyphenchar=0` and `\postexhyphenchar=0`. When you assign the values of one of these four parameters, 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 are ignored right now, but eventually either the limitation will be removed or perhaps it will become possible 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.

5.6 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 dependent 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 word 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-overruled, routine continues to function properly.

Although we could improve the situation the reality is that in modern OpenType fonts ligatures can be constructed in many ways: by replacing a sequence of characters by one glyph, or by selectively replacing individual glyphs, or by kerning, or any combination of this. Add to that contextual analysis and it will be clear that we have to let Lua do that job instead. The generic font handler that we provide (which is part of ConTeXt) distinguishes between base mode (which essentially is what we describe here and which delegates the task to TeX) and node mode (which deals with more complex fonts).

Let’s look at an example. Take the word `office`, hyphenated `of-fice`, using a ‘normal’ font with all the `f-f` and `f-i` type 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 let us assume that there is also a hyphenation point between the `f` and the `i`, to create `of-f-ice`. Then 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.



Here is that nested solution again, in a different representation:

| | PRE | POST | REPLACE |
|---------|-----------|-------|-------------|
| topdisc | f- (1) | | sub 1 sub 2 |
| sub 1 | f- (2) | i (3) | <fi> (4) |
| sub 2 | <ff>- (5) | i (6) | <ffi> (7) |

When line breaking is choosing its breakpoints, the following fields will eventually be selected:

| | |
|----------|-----------|
| of-f-ice | f- (1) |
| | f- (2) |
| | i (3) |
| of-fice | f- (1) |
| | <fi> (4) |
| off-ice | <ff>- (5) |
| | i (6) |
| office | <ffi> (7) |

The current solution in Lua_T_E_X is not able to handle nested discretionaries, but it is in fact smart enough to handle this fictional of-f-ice example. It does so by combining two sequential discretionary nodes as if they were a single object (where the second discretionary node is treated as an extension of the first node).

One can observe that the of-f-ice and off-ice cases both end with the same actual post replacement list (i), and that this would be the case even if i was the first item of a potential following ligature like ic. This allows Lua_T_E_X to do away with one of the fields, and thus make the whole stuff fit into just two discretionary nodes.

The mapping of the seven list fields to the six fields in this discretionary node pair is as follows:

| FIELD | DESCRIPTION |
|---------------|-------------|
| disc1.pre | f- (1) |
| disc1.post | <fi> (4) |
| disc1.replace | <ffi> (7) |
| disc2.pre | f- (2) |
| disc2.post | i (3,6) |
| disc2.replace | <ff>- (5) |

What is actually generated after ligaturing has been applied is therefore:

```
{0}{{f-},
  {<fi>},
  {<ffi>}}
{{f-},
  {i},
  {<ff>-}}{c}{e}
```

The two discretionaries have different subtypes from a discretionary appearing on its own: the first has subtype 4, and the second has subtype 5. The need for these special subtypes stems



from the fact that not all of the fields appear in their ‘normal’ location. The second discretionary especially looks odd, with things like the `<ff>`- appearing in `disc2.replace`. The fact that some of the fields have different meanings (and different processing code internally) is what makes it necessary to have different subtypes: this enables Lua \TeX to distinguish this sequence of two joined discretionary nodes from the case of two standalone discretions appearing in a row.

Of course there is still that relationship with fonts: ligatures can be implemented by mapping a sequence of glyphs onto one glyph, but also by selective replacement and kerning. This means that the above examples are just representing the traditional approach.

5.7 Breaking paragraphs into lines

This code is almost unchanged, but because of the above-mentioned changes with respect to discretions and ligatures, line breaking will potentially be different from traditional \TeX . The actual line breaking code is still based on the \TeX 82 algorithms, and it does not expect there to be discretions inside of discretions. But, as patterns evolve and font handling can influence discretions, you need to be aware of the fact that long term consistency is not an engine matter only.

But that situation is now fairly common in Lua \TeX , due to the changes to the ligaturing mechanism. And also, the Lua \TeX discretionary nodes are implemented slightly different from the \TeX 82 nodes: the `no_break` text is now embedded inside the `disc` node, where previously these nodes kept their place in the horizontal list. In traditional \TeX the discretionary node contains a counter indicating how many nodes to skip, but in Lua \TeX we store the `pre`, `post` and `replace` text in the discretionary node.

The combined effect of these two differences is that Lua \TeX does not always use all of the potential breakpoints in a paragraph, especially when fonts with many ligatures are used. Of course kerning also complicates matters here.

5.8 The `lang` library

5.8.1 `new` and `id`

This library provides the interface to Lua \TeX '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)
```



The number returned is the internal `\language` id number this object refers to.

5.8.2 hyphenation

You can hyphenate a string directly with:

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

5.8.3 clear_hyphenation and clean

This either returns the current hyphenation exceptions for this language, or adds new ones. The syntax of the string is explained in section 5.4.

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

This call clears the exception dictionary (string) for this language.

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

This function creates a hyphenation key from the supplied hyphenation value. The syntax of the argument string is explained in section 5.4. This function is useful if you want to do something else based on the words in a dictionary file, like spell-checking.

5.8.4 patterns and clear_patterns

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

This adds additional patterns for this language object, or returns the current set. The syntax of this string is explained in section 5.4.

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

This can be used to clear the pattern dictionary for a language.

5.8.5 hyphenationmin

This function sets (or gets) the value of the \TeX parameter `\hyphenationmin`.

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

5.8.6 [pre|post][ex|]hyphenchar

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



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

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

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

These two are used to get or set the ‘pre-break’ and ‘post-break’ hyphen characters for implicit hyphenation in this language. The initial values are decimal 45 (hyphen) and decimal 0 (indicating emptiness).

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

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

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

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

These gets or set the ‘pre-break’ and ‘post-break’ hyphen characters for explicit hyphenation in this language. Both are initially decimal 0 (indicating emptiness).

5.8.7 hyphenate

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

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

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

Hyphenation works only on ‘characters’, a special subtype of all the glyph nodes with the node subtype having the value 1. Glyph modes with different subtypes are not processed. See section 5.2 for more details.

5.8.8 [set|get]hjcode

The following two commands can be used to set or query hj codes:

```
lang.sethjcode(<language> l, <number> char, <number> usedchar)
```

```
<number> usedchar = lang.gethjcode(<language> l, <number> char)
```

When you set a hjcode the current sets get initialized unless the set was already initialized due to `\savingsjcodes` being larger than zero.





6 Font structure

6.1 The font tables

All T_EX 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 ‘`vf`’ means that this key will be created by the `font.read_vf()` routine, ‘`tfm`’ means that the key will be created by the `font.read_tfm()` routine, and ‘`used`’ means whether or not the LuaT_EX engine itself will do something with the key. The top-level keys in the table are as follows:

| KEY | VF | TFM | USED | VALUE TYPE | DESCRIPTION |
|----------------------------|-----|-----|------|------------|--|
| <code>name</code> | yes | yes | yes | string | metric (file) name |
| <code>area</code> | no | yes | yes | string | (directory) location, typically empty |
| <code>used</code> | no | yes | yes | boolean | indicates usage (initial: false) |
| <code>characters</code> | yes | yes | yes | table | the defined glyphs of this font |
| <code>checksum</code> | yes | yes | no | number | default: 0 |
| <code>designsize</code> | no | yes | yes | number | expected size (default: 655360 == 10pt) |
| <code>direction</code> | no | yes | yes | number | default: 0 |
| <code>encodingbytes</code> | no | no | yes | number | default: depends on format |
| <code>encodingname</code> | no | no | yes | string | encoding name |
| <code>fonts</code> | yes | no | yes | table | locally used fonts |
| <code>psname</code> | no | no | yes | string | This is the PostScript fontname in the incoming font source, and it's used as font-name identifier in the pdf output. This has to be a valid string, e.g. no spaces and such, as the backend will not do a cleanup. This gives complete control to the loader. |
| <code>fullname</code> | no | no | yes | string | output font name, used as a fallback in the pdf output if the <code>psname</code> is not set |
| <code>subfont</code> | no | no | yes | number | default: 0, index in (ttc) font with multiple fonts |
| <code>header</code> | yes | no | no | string | header comments, if any |
| <code>hyphenchar</code> | no | no | yes | number | default: T _E X's <code>\hyphenchar</code> |
| <code>parameters</code> | no | yes | yes | hash | default: 7 parameters, all zero |
| <code>size</code> | no | yes | yes | number | the required scaling (by default the same as <code>designsize</code>) |
| <code>skewchar</code> | no | no | yes | number | default: T _E X's <code>\skewchar</code> |
| <code>type</code> | yes | no | yes | string | basic type of this font |
| <code>format</code> | no | no | yes | string | disk format type |
| <code>embedding</code> | no | no | yes | string | pdf inclusion |
| <code>filename</code> | no | no | yes | string | the name of the font on disk |



| | | | | | |
|------------------|----|-----|-----|---------|---|
| tounicode | no | yes | yes | number | When this is set to 1 Lua _T _E _X assumes per-glyph tounicode entries are present in the font. |
| stretch | no | no | yes | number | the ‘stretch’ value from <code>\expandglyphsinfont</code> |
| shrink | no | no | yes | number | the ‘shrink’ value from <code>\expandglyphsinfont</code> |
| step | no | no | yes | number | the ‘step’ value from <code>\expandglyphsinfont</code> |
| expansion_factor | no | no | no | number | the actual expansion factor of an expanded font |
| attributes | no | no | yes | string | the <code>\pdffontattr</code> |
| cache | no | no | yes | string | This key controls caching of the Lua table on the _T _E _X end where yes means: use a reference to the table that is passed to Lua _T _E _X (this is the default), and no means: don’t store the table reference, don’t cache any Lua data for this font while <code>renew</code> means: don’t store the table reference, but save a reference to the table that is created at the first access to one of its fields in the font. |
| nomath | no | no | yes | boolean | This key allows a minor speedup for text fonts. If it is present and true, then Lua _T _E _X will not check the character entries for math-specific keys. |
| oldmath | no | no | yes | boolean | This key flags a font as representing an old school _T _E _X math font and disables the OpenType code path. |
| slant | no | no | yes | number | This parameter will tilt the font and does the same as <code>SlantFont</code> in the map file for Type1 fonts. |
| extend | no | no | yes | number | This parameter will scale the font horizontally and does the same as <code>ExtendFont</code> in the map file for Type1 fonts. |
| squeeze | no | no | yes | number | This parameter will scale the font vertically and has no equivalent in the map file. |
| width | no | no | yes | number | The backend will inject pdf operators that set the penwidth. The value is (as usual in _T _E _X) divided by 1000. It works with the mode file. |
| mode | no | no | yes | number | The backend will inject pdf operators that relate to the drawing mode with 0 being a fill, 1 being an outline, 2 both draw and fill and 3 no painting at all. |

The saved reference in the cache option is thread-local, so be careful when you are using corou-



tines: an error will be thrown if the table has been cached in one thread, but you reference it from another thread.

The key name is always required. The keys `stretch`, `shrink`, `step` only have meaning when used together: they can be used to replace a post-loading `\expandglyphsinfont` command. The `auto_expand` option is not supported in LuaTeX. In fact, the primitives that create expanded or protruding copies are probably only useful when used with traditional fonts because all these extra OpenType properties are kept out of the picture. The `expansion_factor` is value that can be present inside a font in `font.fonts`. It is the actual expansion factor (a value between `-shrink` and `stretch`, with `step step`) of a font that was automatically generated by the font expansion algorithm.

The `subfont` parameter can be used to specify the subfont in a `ttc` font. When given, it is used instead of the `psname` and `fullname` combination. The first subfont has number 1. A zero value signals using the names as lookup.

Because we store the actual state of expansion with each glyph and don't have special font instances, we can change some font related parameters before lines are constructed, like:

```
font.setexpansion(font.current(),100,100,20)
```

This is mostly meant for experiments (or an optimizing routing written in Lua) so there is no primitive.

The key `attributes` can be used to set font attributes in the pdf file. 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:

| # | DIR | # | DIR | # | DIR | # | DIR |
|---|-----|---|-----|----|-----|----|-----|
| 0 | LT | 4 | RT | 8 | TT | 12 | BT |
| 1 | LL | 5 | RL | 9 | TL | 13 | BL |
| 2 | LB | 6 | RB | 10 | TB | 14 | BB |
| 3 | LR | 7 | RR | 11 | TR | 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. Keep in mind that LuaTeX has a bit different directional model so these values are not used for anything.

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 are:

| NAME | REMAPPING |
|----------------------------|-----------|
| <code>slant</code> | 1 |
| <code>space</code> | 2 |
| <code>space_stretch</code> | 3 |
| <code>space_shrink</code> | 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 an 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).

Each character hash itself is a hash. For example, here is the character ‘f’ (decimal 102) in the font `cmr10` at 10pt. The numbers that represent dimensions are in scaled 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 | VF | TFM | USED | TYPE | DESCRIPTION |
|-------------------------------|-----|-----|-------|--------|---|
| <code>width</code> | yes | yes | yes | number | character’s width, in sp (default 0) |
| <code>height</code> | no | yes | yes | number | character’s height, in sp (default 0) |
| <code>depth</code> | no | yes | yes | number | character’s depth, in sp (default 0) |
| <code>italic</code> | no | yes | yes | number | character’s italic correction, in sp (default zero) |
| <code>top_accent</code> | no | no | maybe | number | character’s top accent alignment place, in sp (default zero) |
| <code>bot_accent</code> | no | no | maybe | number | character’s bottom accent alignment place, in sp (default zero) |
| <code>left_protruding</code> | no | no | maybe | number | character’s <code>\lrcode</code> |
| <code>right_protruding</code> | no | no | maybe | number | character’s <code>\rrcode</code> |



| | | | | | |
|-------------------------------|-----|-----|-------|---------|---|
| <code>expansion_factor</code> | no | no | maybe | number | character's <code>\efcode</code> |
| <code>tounicode</code> | no | no | maybe | string | character's Unicode equivalent(s), in utf-16BE hexadecimal format |
| <code>next</code> | no | yes | yes | number | the 'next larger' character index |
| <code>extensible</code> | no | yes | yes | table | the constituent parts of an extensible recipe |
| <code>vert_variants</code> | no | no | yes | table | constituent parts of a vertical variant set |
| <code>horiz_variants</code> | no | no | yes | table | constituent parts of a horizontal variant set |
| <code>kerns</code> | no | yes | yes | table | kerning information |
| <code>ligatures</code> | no | yes | yes | table | ligaturing information |
| <code>commands</code> | yes | no | yes | array | virtual font commands |
| <code>name</code> | no | no | no | string | the character (PostScript) name |
| <code>index</code> | no | no | yes | number | the (OpenType or TrueType) font glyph index |
| <code>used</code> | no | yes | yes | boolean | typeset already (default: false) |
| <code>mathkern</code> | no | no | yes | table | math cut-in specifications |

The values of `top_accent`, `bot_accent` and `mathkern` are used only for math accent and superscript placement, see page 107 in this manual for details. The values of `left_protruding` and `right_protruding` are used only when `\protrudechars` is non-zero. Whether or not `expansion_factor` is used depends on the font's global expansion settings, as well as on the value of `\adjustspacing`.

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. The string format is exactly the format that is expected by Adobe CMap files (utf-16BE in hexadecimal encoding), minus the enclosing angle brackets. For instance the `tounicode` for a `fi` ligature would be `00660069`. When you pass a number the conversion will be done for you.

A math character can have a `next` field that points to a next larger shape. However, the presence of `extensible` will overrule `next`, if that is also present. The `extensible` field in turn can be overruled by `vert_variants`, the OpenType version. The `extensible` table is very simple:

| KEY | TYPE | DESCRIPTION |
|------------------|--------|----------------------------|
| <code>top</code> | number | top character index |
| <code>mid</code> | number | middle character index |
| <code>bot</code> | number | bottom character index |
| <code>rep</code> | number | repeatable character index |

The `horiz_variants` and `vert_variants` are arrays of components. Each of those components is itself a hash of up to five keys:

| KEY | TYPE | EXPLANATION |
|-----------------------|--------|--|
| <code>glyph</code> | number | The character index. Note that this is an encoding number, not a name. |
| <code>extender</code> | number | One (1) if this part is repeatable, zero (0) otherwise. |
| <code>start</code> | number | The maximum overlap at the starting side (in scaled points). |



end number The maximum overlap at the ending side (in scaled points).
 advance number The total advance width of this item. It can be zero or missing, then the natural size of the glyph for character component is used.

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 of 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 T_EX. When T_EX 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 |
|------------------------------------|--------|----------------------------|-------------------|
| <code>l + r =: n</code> | 0 | <code>=:</code> | <code> n</code> |
| <code>l + r =: n</code> | 1 | <code>=: </code> | <code> nr</code> |
| <code>l + r =: n</code> | 2 | <code> =:</code> | <code> ln</code> |
| <code>l + r =: n</code> | 3 | <code> =: </code> | <code> lnr</code> |
| <code>l + r =: > n</code> | 5 | <code>=: ></code> | <code>n r</code> |
| <code>l + r =: > n</code> | 6 | <code> =: ></code> | <code>l n</code> |
| <code>l + r =: > n</code> | 7 | <code> =: ></code> | <code>l nr</code> |
| <code>l + r =: >> n</code> | 11 | <code> =: >></code> | <code>ln r</code> |

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.

6.2 Real fonts

Whether or not a T_EX 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 are:

| VALUE | DESCRIPTION |
|----------------------|------------------------|
| <code>real</code> | this is a base font |
| <code>virtual</code> | 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. This is true for traditional T_EX fonts that communicate via tfm files.
- ▶ The type of the disk font file, for instance a bitmap file or an outline Type1, TrueType or OpenType font.
- ▶ The level of embedding requested, although in most cases a subset of characters is embedded. The times when nothing got embedded are (in our opinion at least) basically gone.

A font that uses anything other than an 8-bit encoding vector has to be written to the pdf in a different way. When the font table has `encodingbytes` set to 2, then it 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, LuaT_EX falls back to the mapfile-based solution used by pdfT_EX and dvips, so that legacy fonts are supported transparently. If a 'wide' font is used, the new subsystem kicks in, and some extra fields have to be present in the font structure. In this case, LuaT_EX does not use a map file at all. These extra fields are: `format`, `embedding`, `fullname`, `cidinfo` (as explained above), `filename`, and the `index` key in the separate characters.

The `format` variable can have the following values. `type3` fonts are provided for backward compatibility only, and do not support the new wide encoding options.

| VALUE | DESCRIPTION |
|-----------------------|--|
| <code>type1</code> | this is a PostScript Type1 font |
| <code>type3</code> | this is a bitmapped (pk) font |
| <code>truetype</code> | this is a TrueType or TrueType-based OpenType font |
| <code>opentype</code> | this is a PostScript-based OpenType font |

Valid values for the `embedding` variable are:

| VALUE | DESCRIPTION |
|---------------------|--|
| <code>no</code> | don't embed the font at all |
| <code>subset</code> | include and attempt to subset the font |
| <code>full</code> | include this font in its entirety |

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, LuaT_EX will run a little bit more efficient because it will not have to re-run the `find*_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 to a more unique one.

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. One way to get the correct



index numbers for Type1 fonts is by loading the font via `fontloader.open` and use the table indices as index fields.

In order to make sure that cut and paste of the final document works okay you can best make sure that there is a `tounicode` vector enforced. Not all pdf viewers handle this right so take Acrobat as reference.

6.3 Virtual fonts

6.3.1 The structure

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

- ▶ Set the top-level key `type` to `virtual`. In most cases it's optional because we look at the `commands` entry anyway.
- ▶ Make sure there is at least one valid entry in `fonts` (see below), although recent versions of Lua_T_E_X add a default entry when this table is missing.
- ▶ Add a `commands` array to those characters that matter. A virtual character can itself point to virtual characters but be careful with nesting as you can create loops and overflow the stack (which often indicates an error anyway).

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 existence of 'type' is enough to prevent Lua_T_E_X from looking for a virtual font on its own. This also works 'in reverse': if you are absolutely certain that a font is not a virtual font, assigning the value `real` to `type` will inhibit Lua_T_E_X from looking for a virtual font file, thereby saving you a disk search. This only matters when we load a `tfm` file.

The `fonts` is an (indexed) Lua table. The values are one- or two-key hashes themselves, each entry indicating one of the base fonts in a virtual font. In case your font is referring to itself, you can use the `font.nextid()` function which returns the index of the next to be defined font which is probably the currently defined one. So, a table looks like this:

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

The first referenced font (at index 1) in this virtual font is `ptmr8a` loaded at 10pt, and the second is `psyr` loaded at a little over 9pt. The third one is a previously defined font that is known to Lua_T_E_X as font id 38. The array index numbers are used by the character command definitions that are part of each character.

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



| COMMAND | ARGUMENTS | 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 | 2 numbers | 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 $ht * wd$, and move right. |
| down | 1 | number | move down on the page |
| right | 1 | number | move right on the page |
| special | 1 | string | output a <code>\special</code> command |
| pdf | 2 | 2 strings | output a pdf literal, the first string is one of origin, page, text, font, direct or raw; if you have one string only origin is assumed |
| lua | 1 | string, function | execute a Lua script when the glyph is embedded; in case of a function it gets the font id and character code passed |
| image | 1 | image | output an image (the argument can be either an <code><image></code> variable or an <code>image_spec</code> table) |
| comment | any | any | the arguments of this command are ignored |

When a font id is set to 0 then it will be replaced by the currently assigned font id. This prevents the need for hackery with future id's. Normally one could use `font.nextid` but when more complex fonts are built in the meantime other instances could have been loaded.

The pdf option also accepts a mode keyword in which case the third argument sets the mode. That option will change the mode in an efficient way (passing an empty string would result in an extra empty lines in the pdf file. This option only makes sense for virtual fonts. The font mode only makes sense in virtual fonts. Modes are somewhat fuzzy and partially inherited from pdf_{TEX}.

| MODE | DESCRIPTION |
|--------|--|
| origin | enter page mode and set the position |
| page | enter page mode |
| text | enter text mode |
| font | enter font mode (kind of text mode, only in virtual fonts) |
| always | finish the current string and force a transform if needed |
| raw | finish the current string |

You always need to check what pdf code is generated because there can be all kind of interferences with optimization in the backend and fonts are complicated anyway. Here is a rather elaborate glyph commands example using such keys:

...



```

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')
  -- { "slot", 2, 97 }, -- an alternative for the previous two
  { "pop" }, -- go all the way back
  { "down", -200000 }, -- move upwards by about 3pt
  { "special", "pdf: 1 0 0 rg" } -- switch to red color
  -- { "pdf", "origin", "1 0 0 rg" } -- switch to red color (alternative)
  { "rule", 500000, 20000 } -- draw a bar
  { "special", "pdf: 0 g" } -- back to black
  -- { "pdf", "origin", "0 g" } -- back to black (alternative)
}
...

```

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 created 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.

The special can have a pdf:, pdf:origin:, pdf:page:, pdf:direct: or pdf:raw: prefix. When you have to concatenate strings using the pdf command might be more efficient.

6.3.2 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 practice, 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).

6.3.3 Example virtual font

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

```

\directlua {
  callback.register('define_font',

```




```

function (name,size)
  if name == 'cmr10-red' then
    local 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" },
        }
      end
    end
    return f
  else
    return font.read_tfm(name,size)
  end
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

```

6.4 The vf library

The `vf` library can be used when Lua code, as defined in the commands of the font, is executed. The functions provided are similar as the commands: `char`, `down`, `fontid`, `image`, `node`, `nop`, `pop`, `push`, `right`, `rule`, `special` and `pdf`. This library has been present for a while but not been advertised and tested much, if only because it's easy to define an invalid font (or mess up the pdf stream). Keep in mind that the Lua snippets are executed each time when a character is output.

6.5 The font library

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

6.5.1 Loading a TFM file

The behaviour documented in this subsection is considered stable in the sense that there will not be backward-incompatible changes any more.



```
<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.

6.5.2 Loading a VF file

The behavior documented in this subsection is considered stable in the sense that there will not be backward-incompatible changes any more.

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

The meaning of the number `s` and the format of the returned table are similar to the ones in the `read_tfm` function.

6.5.3 The fonts array

The whole table of $\text{T}_{\text{E}}\text{X}$ fonts is accessible from Lua using a virtual array.

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

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)
```

Note that at the moment, each access to the `font.fonts` or call to `font.getfont` creates a Lua table for the whole font unless you cached it. If you want a copy of the internal data you can use `font.getcopy`:

```
<table> f = font.getcopy(<number> n)
```

This one will return a table of the parameters as known to $\text{T}_{\text{E}}\text{X}$. These can be different from the ones in the cached table:

```
<table> p = font.getparameters(<number> n)
```

Also note the following: assignments can only be made to fonts that have already been defined in $\text{T}_{\text{E}}\text{X}$, 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.



6.5.4 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).

6.5.5 Defining a font directly

You can define your own font into `font.fonts` by calling this function:

```
<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. An alternative call is:

```
<number> i =  
    font.define(<number> n, <table> f)
```

Where the first argument is a reserved font id (see below).

6.5.6 Extending a font

Within reasonable bounds you can extend a font after it has been defined. Because some properties are best left unchanged this is limited to adding characters.

```
font.addcharacters(<number> n, <table> f)
```

The table passed can have the fields `characters` which is a (sub)table like the one used in `define`, and for virtual fonts a `fonts` table can be added. The characters defined in the `characters` table are added (when not yet present) or replace an existing entry. Keep in mind that replacing can have side effects because a character already can have been used. Instead of posing restrictions we expect the user to be careful. (The `setfont` helper is a more drastic replacer.)

6.5.7 Projected next font id

```
<number> i =  
    font.nextid()
```

This returns the font id number that would be returned by a `font.define` call if it was executed at this spot in the code flow. This is useful for virtual fonts that need to reference themselves. If you pass `true` as argument, the id gets reserved and you can pass to `font.define` as first argument. This can be handy when you create complex virtual fonts.

```
<number> i =
```



```
font.nextid(true)
```

6.5.8 Font ids

```
<number> i =  
  font.id(<string> csname)
```

This returns the font id associated with `csname`, or `-1` if `csname` is not defined.

```
<number> i =  
  font.max()
```

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

```
<number> i = font.current()  
font.current(<number> i)
```

This gets or sets the currently used font number.

6.5.9 Iterating over all fonts

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

This is an iterator over each of the defined $\text{T}_{\text{E}}\text{X}$ 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.

6.5.10 `\glyphdimensionsmode`

Already in the early days of $\text{LuaT}_{\text{E}}\text{X}$ the decision was made to calculate the effective height and depth of glyphs in a way that reflected the applied vertical offset. The height got that offset added, the depth only when the offset was larger than zero. We can now control this in more detail with this mode parameter. An offset is added to the height and/or subtracted from the depth. The effective values are never negative. The zero mode is the default.

| VALUE | EFFECT |
|-------|---|
| 0 | the old behavior: add the offset to the height and only subtract the offset only from the depth when it is positive |
| 1 | add the offset to the height and subtract it from the depth |
| 2 | add the offset to the height and subtract it from the depth but keep the maxima of the current and previous results |
| 3 | use the height and depth of the glyph, so no offset is applied |



6.5.11 `\discretionaryligaturemode`

This parameter controls how complex ligatures interact with discretionaries (as injected by the hyphenator). The non-zero values prevent the construction of so called init and select discretionaries.

| 0 | 1 | 2 |
|-----|-----|-----|
| xx- | xx- | xx- |
| f- | f- | ff- |
| f- | fi- | i- |
| i- | xx | xx |
| xx | | |

6.5.12 `\tracinglostchars`

This tracer reports missing characters. By design we delay this till the backend included them, when math typesetting needs them, or when a virtual font is created (1, 2, 3). Per request of the L^AT_EX team we have two extra options that report in an earlier stage i.e. when the glyphs are packaged or processed during line breaking (4 and 5).

| EFFECT |
|--------------------------------------|
| 0 nothing |
| 1 warning only to log file |
| 2 warning and force terminal |
| 3 error |
| 4 early warning (and force terminal) |
| > 4 early error |





7 Math

7.1 Traditional alongside OPENTYPE

The handling of mathematics in Lua \TeX differs quite a bit from how \TeX 82 (and therefore pdf \TeX) handles math. First, Lua \TeX adds primitives and extends some others so that Unicode input can be used easily. Second, all of \TeX 82's internal special values (for example for operator spacing) have been made accessible and changeable via control sequences. Third, there are extensions that make it easier to use OpenType math fonts. And finally, there are some extensions that have been proposed or considered in the past that are now added to the engine.

7.2 Unicode math characters

Character handling is now extended up to the full Unicode range (the $\backslash U$ prefix), which is compatible with \XeTeX .

The math primitives from \TeX are kept as they are, except for the ones that convert from input to math commands: \mathcode , and \delcode . These two now allow for a 21-bit character argument on the left hand side of the equals sign.

Some of the new Lua \TeX primitives read more than one separate value. This is shown in the tables below by a plus sign.

The input for such primitives would look like this:

```
 $\def\overbrace{\backslash Umathaccent 0 1 "23DE }$ 
```

The altered \TeX 82 primitives are:

| PRIMITIVE | MIN | MAX | = | MIN | MAX |
|-------------|-----|--------|---|-----|--------|
| \mathcode | 0 | 10FFFF | = | 0 | 8000 |
| \delcode | 0 | 10FFFF | = | 0 | FFFFFF |

The unaltered ones are:

| PRIMITIVE | MIN | MAX |
|----------------|-----|----------|
| \mathchardef | 0 | 8000 |
| \mathchar | 0 | 7FFF |
| \mathaccent | 0 | 7FFF |
| \delimiter | 0 | 7FFFFFFF |
| \radical | 0 | 7FFFFFFF |

For practical reasons \mathchardef will silently accept values larger than $0x8000$ and interpret it as $\backslash Umathcharnumdef$. This is needed to satisfy older macro packages.

The following new primitives are compatible with \XeTeX :

| PRIMITIVE | MIN | MAX | MIN | MAX |
|---------------------------|-------|-------------|-----|-----|
| $\backslash Umathchardef$ | 0+0+0 | 7+FF+10FFFF | | |



| | | | | |
|---|------------------------|--------------------------|--------------------------|--------------------------|
| <code>\Umathcharnumdef⁵</code> | <code>-80000000</code> | <code>7FFFFFFF</code> | | |
| <code>\Umathcode</code> | <code>0</code> | <code>10FFFF</code> | <code>= 0+0+0</code> | <code>7+FF+10FFFF</code> |
| <code>\Udelcode</code> | <code>0</code> | <code>10FFFF</code> | <code>= 0+0</code> | <code>FF+10FFFF</code> |
| <code>\Umathchar</code> | <code>0+0+0</code> | <code>7+FF+10FFFF</code> | | |
| <code>\Umathaccent</code> | <code>0+0+0</code> | <code>7+FF+10FFFF</code> | | |
| <code>\Udelimiter</code> | <code>0+0+0</code> | <code>7+FF+10FFFF</code> | | |
| <code>\Uradical</code> | <code>0+0</code> | <code>FF+10FFFF</code> | | |
| <code>\Umathcharnum</code> | <code>-80000000</code> | <code>7FFFFFFF</code> | | |
| <code>\Umathcodenum</code> | <code>0</code> | <code>10FFFF</code> | <code>= -80000000</code> | <code>7FFFFFFF</code> |
| <code>\Udelcodenum</code> | <code>0</code> | <code>10FFFF</code> | <code>= -80000000</code> | <code>7FFFFFFF</code> |

Specifications typically look like:

```
\Umathchardef\xx="1"0"456
\Umathcode 123="1"0"789
```

The new primitives that deal with delimiter-style objects do not set up a ‘large family’. Selecting a suitable size for display purposes is expected to be dealt with by the font via the `\Umathoperatorsize` parameter.

For some of these primitives, all information is packed into a single signed integer. For the first two (`\Umathcharnum` and `\Umathcodenum`), the lowest 21 bits are the character code, the 3 bits above that represent the math class, and the family data is kept in the topmost bits. This means that the values for math families 128–255 are actually negative. For `\Udelcodenum` there is no math class. The math family information is stored in the bits directly on top of the character code. Using these three commands is not as natural as using the two- and three-value commands, so unless you know exactly what you are doing and absolutely require the speedup resulting from the faster input scanning, it is better to use the verbose commands instead.

The `\Umathaccent` command accepts optional keywords to control various details regarding math accents. See section 7.6.2 below for details.

There are more new primitives and all of these will be explained in following sections:

| PRIMITIVE | VALUE RANGE (IN HEX) |
|-------------------------------|--------------------------------|
| <code>\Uroot</code> | <code>0 + 0-FF + 10FFFF</code> |
| <code>\Uoverdelimiter</code> | <code>0 + 0-FF + 10FFFF</code> |
| <code>\Underdelimiter</code> | <code>0 + 0-FF + 10FFFF</code> |
| <code>\Udelimiterover</code> | <code>0 + 0-FF + 10FFFF</code> |
| <code>\Udelimiterunder</code> | <code>0 + 0-FF + 10FFFF</code> |

Instead of the pseudo class variable (7) you can use a family number as signal for using the current family. This permits classifying characters with a class and still let the family adapt. The trigger family is set with `\variablefam`. So:

```
\variablefam"24
\Umathchardef\foo "3 "24 123
\foo \fam9
```

Results in a curly left brace taken from family 9 with class ‘relation’ and spacing around it will be accordingly.



7.3 Math styles

7.3.1 `\mathstyle`

It is possible to discover the math style that will be used for a formula in an expandable fashion (while the math list is still being read). To make this possible, LuaTeX adds the new primitive: `\mathstyle`. This is a ‘convert command’ like e.g. `\romannumeral`: its value can only be read, not set.

The returned value is between 0 and 7 (in math mode), or -1 (all other modes). For easy testing, the eight math style commands have been altered so that they can be used as numeric values, so you can write code like this:

```
\ifnum\mathstyle=\textstyle
  \message{normal text style}
\else \ifnum\mathstyle=\crampedtextstyle
  \message{cramped text style}
\fi \fi
```

Sometimes you won’t get what you expect so a bit of explanation might help to understand what happens. When math is parsed and expanded it gets turned into a linked list. In a second pass the formula will be build. This has to do with the fact that in order to determine the automatically chosen sizes (in for instance fractions) following content can influence preceding sizes. A side effect of this is for instance that one cannot change the definition of a font family (and thereby reusing numbers) because the number that got used is stored and used in the second pass (so changing `\fam 12` mid-formula spoils over to preceding use of that family).

The style switching primitives like `\textstyle` are turned into nodes so the styles set there are frozen. The `\mathchoice` primitive results in four lists being constructed of which one is used in the second pass. The fact that some automatic styles are not yet known also means that the `\mathstyle` primitive expands to the current style which can of course be different from the one really used. It’s a snapshot of the first pass state. As a consequence in the following example you get a style number (first pass) typeset that can actually differ from the used style (second pass). In the case of a math choice used ungrouped, the chosen style is used after the choice too, unless you group.

```
[a:\mathstyle]\quad
\bgroup
\mathchoice
  {\bf \scriptstyle      (x:d :\mathstyle)}
  {\bf \scriptscriptstyle (x:t :\mathstyle)}
  {\bf \scriptscriptstyle (x:s :\mathstyle)}
  {\bf \scriptscriptstyle (x:ss:\mathstyle)}
\egroup
\quad[b:\mathstyle]\quad
\mathchoice
  {\bf \scriptstyle      (y:d :\mathstyle)}
  {\bf \scriptscriptstyle (y:t :\mathstyle)}
```



```

    {\bf \scriptscriptstyle (y:s :\mathstyle)}
    {\bf \scriptscriptstyle (y:ss:\mathstyle)}
\quad[c:\mathstyle]\quad
\bgroup
\mathchoice
    {\bf \scriptstyle      (z:d :\mathstyle)}
    {\bf \scriptscriptstyle (z:t :\mathstyle)}
    {\bf \scriptscriptstyle (z:s :\mathstyle)}
    {\bf \scriptscriptstyle (z:ss:\mathstyle)}
\egroup
\quad[d:\mathstyle]

```

This gives:

$$[a : 0] \quad (\mathbf{x:d:4}) \quad [b : 0] \quad (\mathbf{y:d:4}) \quad [c:0] \quad (\mathbf{z:s:6}) \quad [d:0]$$

$$[a : 2] \quad (\mathbf{x:t:6}) \quad [b : 2] \quad (\mathbf{y:t:6}) \quad [c:2] \quad (\mathbf{z:ss:6}) \quad [d:2]$$

Using `\begingroup ... \endgroup` instead gives:

$$[a : 0] \quad (\mathbf{x:d:4}) \quad [b:0] \quad (\mathbf{y:s:6}) \quad [c:0] \quad (\mathbf{z:ss:6}) \quad [d:0]$$

$$[a : 2] \quad (\mathbf{x:t:6}) \quad [b:2] \quad (\mathbf{y:ss:6}) \quad [c:2] \quad (\mathbf{z:ss:6}) \quad [d:2]$$

This might look wrong but it's just a side effect of `\mathstyle` expanding to the current (first pass) style and the number being injected in the list that gets converted in the second pass. It all makes sense and it illustrates the importance of grouping. In fact, the math choice style being effective afterwards has advantages. It would be hard to get it otherwise.

7.3.2 `\Ustack`

There are a few math commands in \TeX where the style that will be used is not known straight from the start. These commands (`\over`, `\atop`, `\overwithdelims`, `\atopwithdelims`) would therefore normally return wrong values for `\mathstyle`. To fix this, $\text{Lua}\TeX$ introduces a special prefix command: `\Ustack`:

$$\mathcal{U}\text{stack } \{a \over b\}$$

The `\Ustack` command will scan the next brace and start a new math group with the correct (numerator) math style.

7.3.3 Cramped math styles

$\text{Lua}\TeX$ has four new primitives to set the cramped math styles directly:

```

\crampeddisplaystyle
\crampedtextstyle
\crampedscriptstyle
\crampedscriptscriptstyle

```



These additional commands are not all that valuable on their own, but they come in handy as arguments to the math parameter settings that will be added shortly.

In Eijkhouts “T_EX by Topic” the rules for handling styles in scripts are described as follows:

- ▶ In any style superscripts and subscripts are taken from the next smaller style. Exception: in display style they are in script style.
- ▶ Subscripts are always in the cramped variant of the style; superscripts are only cramped if the original style was cramped.
- ▶ In an `.. \over ..` formula in any style the numerator and denominator are taken from the next smaller style.
- ▶ The denominator is always in cramped style; the numerator is only in cramped style if the original style was cramped.
- ▶ Formulas under a `\sqrt` or `\overline` are in cramped style.

In LuaT_EX one can set the styles in more detail which means that you sometimes have to set both normal and cramped styles to get the effect you want. (Even) if we force styles in the script using `\scriptstyle` and `\crampedscriptstyle` we get this:

| STYLE | EXAMPLE |
|---------------|-------------------|
| default | $b_{x=xx}^{x=xx}$ |
| script | $b_{x=xx}^{x=xx}$ |
| crampedscript | $b_{x=xx}^{x=xx}$ |

Now we set the following parameters

```
\Umathordrelspacing\scriptstyle=30mu
\Umathordordspacing\scriptstyle=30mu
```

This gives a different result:

| STYLE | EXAMPLE |
|---------------|---------------------------|
| default | $b_{x=xx}^{x=xx} \quad x$ |
| script | $b_x^{x=xx} \quad x$ |
| crampedscript | $b_{x=xx}^{x=xx} \quad x$ |

But, as this is not what is expected (visually) we should say:

```
\Umathordrelspacing\scriptstyle=30mu
\Umathordordspacing\scriptstyle=30mu
\Umathordrelspacing\crampedscriptstyle=30mu
\Umathordordspacing\crampedscriptstyle=30mu
```

Now we get:

| STYLE | EXAMPLE |
|---------------|----------------------|
| default | $b_x^{x=xx} \quad x$ |
| script | $b_x^{x=xx} \quad x$ |
| crampedscript | $b_x^{x=xx} \quad x$ |



7.4 Math parameter settings

7.4.1 Many new `\Umath*` primitives

In Lua \TeX , the font dimension parameters that \TeX used in math typesetting are now accessible via primitive commands. In fact, refactoring of the math engine has resulted in many more parameters than were not accessible before.

| PRIMITIVE NAME | DESCRIPTION |
|--|---|
| <code>\Umathquad</code> | the width of 18 mu's |
| <code>\Umathaxis</code> | height of the vertical center axis of the math formula above the baseline |
| <code>\Umathoperator size</code> | minimum size of large operators in display mode |
| <code>\Umathoverbarkern</code> | vertical clearance above the rule |
| <code>\Umathoverbarrule</code> | the width of the rule |
| <code>\Umathoverbarvgap</code> | vertical clearance below the rule |
| <code>\Umathunderbarkern</code> | vertical clearance below the rule |
| <code>\Umathunderbarrule</code> | the width of the rule |
| <code>\Umathunderbarvgap</code> | vertical clearance above the rule |
| <code>\Umathradicalkern</code> | vertical clearance above the rule |
| <code>\Umathradicalrule</code> | the width of the rule |
| <code>\Umathradicalvgap</code> | vertical clearance below the rule |
| <code>\Umathradicaldegreebefore</code> | the forward kern that takes place before placement of the radical degree |
| <code>\Umathradicaldegreeafter</code> | the backward kern that takes place after placement of the radical degree |
| <code>\Umathradicaldegreeraise</code> | this is the percentage of the total height and depth of the radical sign that the degree is raised by; it is expressed in percents, so 60% is expressed as the integer 60 |
| <code>\Umathstackvgap</code> | vertical clearance between the two elements in a <code>\atop</code> stack |
| <code>\Umathstacknumup</code> | numerator shift upward in <code>\atop</code> stack |
| <code>\Umathstackdenomdown</code> | denominator shift downward in <code>\atop</code> stack |
| <code>\Umathfractionrule</code> | the width of the rule in a <code>\over</code> |
| <code>\Umathfractionnumvgap</code> | vertical clearance between the numerator and the rule |
| <code>\Umathfractionnumup</code> | numerator shift upward in <code>\over</code> |
| <code>\Umathfractiondenomvgap</code> | vertical clearance between the denominator and the rule |
| <code>\Umathfractiondenomdown</code> | denominator shift downward in <code>\over</code> |
| <code>\Umathfractiondelsize</code> | minimum delimiter size for <code>\dotswithdelims</code> |
| <code>\Umathlimitabovevgap</code> | vertical clearance for limits above operators |
| <code>\Umathlimitabovebgap</code> | vertical baseline clearance for limits above operators |
| <code>\Umathlimitabovekern</code> | space reserved at the top of the limit |
| <code>\Umathlimitbelowvgap</code> | vertical clearance for limits below operators |
| <code>\Umathlimitbelowbgap</code> | vertical baseline clearance for limits below operators |
| <code>\Umathlimitbelowkern</code> | space reserved at the bottom of the limit |
| <code>\Umathoverdelimitervgap</code> | vertical clearance for limits above delimiters |
| <code>\Umathoverdelimiterbgap</code> | vertical baseline clearance for limits above delimiters |



| | |
|--|---|
| <code>\Umathunderdelimitervgap</code> | vertical clearance for limits below delimiters |
| <code>\Umathunderdelimiterbgap</code> | vertical baseline clearance for limits below delimiters |
| <code>\Umathsubshiftdrop</code> | subscript drop for boxes and subformulas |
| <code>\Umathsubshiftdown</code> | subscript drop for characters |
| <code>\Umathsupshiftdrop</code> | superscript drop (raise, actually) for boxes and subformulas |
| <code>\Umathsupshiftdown</code> | superscript raise for characters |
| <code>\Umathsubsupshiftdown</code> | subscript drop in the presence of a superscript |
| <code>\Umathsubtopmax</code> | the top of standalone subscripts cannot be higher than this above the baseline |
| <code>\Umathsupbottommin</code> | the bottom of standalone superscripts cannot be less than this above the baseline |
| <code>\Umathsubsubbottommax</code> | the bottom of the superscript of a combined super- and subscript be at least as high as this above the baseline |
| <code>\Umathsubsupvgap</code> | vertical clearance between super- and subscript |
| <code>\Umathspaceafterscript</code> | additional space added after a super- or subscript |
| <code>\Umathconnectoroverlapmin</code> | minimum overlap between parts in an extensible recipe |

Each of the parameters in this section can be set by a command like this:

```
\Umathquad\displaystyle=1em
```

they obey grouping, and you can use `\the\Umathquad\displaystyle` if needed.

7.4.2 Font-based math parameters

While it is nice to have these math parameters available for tweaking, it would be tedious to have to set each of them by hand. For this reason, Lua \TeX initializes a bunch of these parameters whenever you assign a font identifier to a math family based on either the traditional math font dimensions in the font (for assignments to math family 2 and 3 using tfm-based fonts like `cmsy` and `cmex`), or based on the named values in a potential `MathConstants` table when the font is loaded via Lua. If there is a `MathConstants` table, this takes precedence over font dimensions, and in that case no attention is paid to which family is being assigned to: the `MathConstants` tables in the last assigned family sets all parameters.

In the table below, the one-letter style abbreviations and symbolic tfm font dimension names match those used in the \TeX book. Assignments to `\textfont` set the values for the cramped and uncramped display and text styles, `\scriptfont` sets the script styles, and `\scriptscriptfont` sets the scriptscript styles, so we have eight parameters for three font sizes. In the tfm case, assignments only happen in family 2 and family 3 (and of course only for the parameters for which there are font dimensions).

Besides the parameters below, Lua \TeX also looks at the ‘space’ font dimension parameter. For math fonts, this should be set to zero.

| VARIABLE / STYLE | TFM / OPENTYPE |
|--|---------------------------|
| <code>\Umathaxis</code> | axis_height AxisHeight |
| ⁶ <code>\Umathoperatorsize</code> | – |



| | |
|--|---|
| D, D' | DisplayOperatorMinHeight |
| ⁹ \Umathfractiondelsize D, D' | delim1 FractionDelimiterDisplayStyleSize |
| ⁹ \Umathfractiondelsize T, T', S, S', SS, SS' | delim2 FractionDelimiterSize |
| \Umathfractiondenomdown D, D' | denom1 FractionDenominatorDisplayStyleShiftDown |
| \Umathfractiondenomdown T, T', S, S', SS, SS' | denom2 FractionDenominatorShiftDown |
| \Umathfractiondenomvgap D, D' | 3*default_rule_thickness FractionDenominatorDisplayStyleGapMin |
| \Umathfractiondenomvgap T, T', S, S', SS, SS' | default_rule_thickness FractionDenominatorGapMin |
| \Umathfractionnumup D, D' | num1 FractionNumeratorDisplayStyleShiftUp |
| \Umathfractionnumup T, T', S, S', SS, SS' | num2 FractionNumeratorShiftUp |
| \Umathfractionnumvgap D, D' | 3*default_rule_thickness FractionNumeratorDisplayStyleGapMin |
| \Umathfractionnumvgap T, T', S, S', SS, SS' | default_rule_thickness FractionNumeratorGapMin |
| \Umathfractionrule | default_rule_thickness FractionRuleThickness |
| \Umathskewedfractionhgap | math_quad/2 SkewedFractionHorizontalGap |
| \Umathskewedfractionvgap | math_x_height SkewedFractionVerticalGap |
| \Umathlimitabovebgap | big_op_spacing3 UpperLimitBaselineRiseMin |
| ¹ \Umathlimitabovekern | big_op_spacing5 0 |
| \Umathlimitabovevgap | big_op_spacing1 UpperLimitGapMin |
| \Umathlimitbelowbgap | big_op_spacing4 LowerLimitBaselineDropMin |
| ¹ \Umathlimitbelowkern | big_op_spacing5 0 |
| \Umathlimitbelowvgap | big_op_spacing2 LowerLimitGapMin |
| \Umathoverdelimitervgap | big_op_spacing1 StretchStackGapBelowMin |
| \Umathoverdelimiterbgap | big_op_spacing3 |



| | |
|--|---|
| | StretchStackTopShiftUp |
| \Umathunderdelimitervgap | big_op_spacing2 StretchStackGapAboveMin |
| \Umathunderdelimitebgap | big_op_spacing4 StretchStackBottomShiftDown |
| \Umathoverbarkern | default_rule_thickness OverbarExtraAscender |
| \Umathoverbarrule | default_rule_thickness OverbarRuleThickness |
| \Umathoverbarvgap | 3*default_rule_thickness OverbarVerticalGap |
| ¹ \Umathquad | math_quad <font_size(f)> |
| \Umathradicalkern | default_rule_thickness RadicalExtraAscender |
| ² \Umathradicalrule | <not set> RadicalRuleThickness |
| ³ \Umathradicalvgap D, D' | default_rule_thickness+abs(math_x_height)/4 RadicalDisplayStyleVerticalGap |
| ³ \Umathradicalvgap T, T', S, S', SS, SS' | default_rule_thickness+abs(default_rule_thickness)/4 RadicalVerticalGap |
| ² \Umathradicaldegreebefore | <not set> RadicalKernBeforeDegree |
| ² \Umathradicaldegreeafter | <not set> RadicalKernAfterDegree |
| ^{2,7} \Umathradicaldegreeraise | <not set> RadicalDegreeBottomRaisePercent |
| ⁴ \Umathspaceafterscript | script_space SpaceAfterScript |
| \Umathstackdenomdown D, D' | denom1 StackBottomDisplayStyleShiftDown |
| \Umathstackdenomdown T, T', S, S', SS, SS' | denom2 StackBottomShiftDown |
| \Umathstacknumup D, D' | num1 StackTopDisplayStyleShiftUp |
| \Umathstacknumup T, T', S, S', SS, SS' | num3 StackTopShiftUp |
| \Umathstackvgap D, D' | 7*default_rule_thickness StackDisplayStyleGapMin |
| \Umathstackvgap T, T', S, S', SS, SS' | 3*default_rule_thickness StackGapMin |
| \Umathsubshiftdown | sub1 |



| | |
|---|---|
| | SubscriptShiftDown |
| \Umathsubshiftdrop | sub_drop SubscriptBaselineDropMin |
| ⁸ \Umathsubsupshiftdown | – SubscriptShiftDownWithSuperscript |
| \Umathsubtopmax | abs(math_x_height*4)/5 SubscriptTopMax |
| \Umathsubsupvgap | 4*default_rule_thickness SubSuperscriptGapMin |
| \Umathsupbottommin | abs(math_x_height/4) SuperscriptBottomMin |
| \Umathsupshiftdrop | sup_drop SuperscriptBaselineDropMax |
| \Umathsupshiftup | sup1 SuperscriptShiftUp |
| D | |
| \Umathsupshiftup | sup2 SuperscriptShiftUp |
| T, S, SS, | |
| \Umathsupshiftup | sup3 SuperscriptShiftUpCramped |
| D', T', S', SS' | |
| \Umathsupsubbottommax | abs(math_x_height*4)/5 SuperscriptBottomMaxWithSubscript |
| \Umathunderbarkern | default_rule_thickness UnderbarExtraDescender |
| \Umathunderbarrule | default_rule_thickness UnderbarRuleThickness |
| \Umathunderbarvgap | 3*default_rule_thickness UnderbarVerticalGap |
| ⁵ \Umathconnectoroverlapmin | 0 MinConnectorOverlap |

Note 1: OpenType fonts set `\Umathlimitabovekern` and `\Umathlimitbelowkern` to zero and set `\Umathquad` to the font size of the used font, because these are not supported in the MATH table,

Note 2: Traditional tfm fonts do not set `\Umathradicalrule` because T_EX82 uses the height of the radical instead. When this parameter is indeed not set when LuaT_EX has to typeset a radical, a backward compatibility mode will kick in that assumes that an oldstyle T_EX font is used. Also, they do not set `\Umathradicaldegreebefore`, `\Umathradicaldegreeafter`, and `\Umathradicaldegreeraise`. These are then automatically initialized to 5/18quad, –10/18quad, and 60.

Note 3: If tfm fonts are used, then the `\Umathradicalvgap` is not set until the first time LuaT_EX has to typeset a formula because this needs parameters from both family 2 and family 3. This provides a partial backward compatibility with T_EX82, but that compatibility is only partial: once the `\Umathradicalvgap` is set, it will not be recalculated any more.

Note 4: When tfm fonts are used a similar situation arises with respect to `\Umathspaceafter-script`: it is not set until the first time LuaT_EX has to typeset a formula. This provides some



backward compatibility with T_EX82. But once the `\Umathspaceafterscript` is set, `\script-space` will never be looked at again.

Note 5: Traditional tfm fonts set `\Umathconnectoroverlapmin` to zero because T_EX82 always stacks extensibles without any overlap.

Note 6: The `\Umathoperatorsize` is only used in `\displaystyle`, and is only set in OpenType fonts. In tfm font mode, it is artificially set to one scaled point more than the initial attempt's size, so that always the 'first next' will be tried, just like in T_EX82.

Note 7: The `\Umathradicaldegreerraise` is a special case because it is the only parameter that is expressed in a percentage instead of a number of scaled points.

Note 8: `SubscriptShiftDownWithSuperscript` does not actually exist in the 'standard' OpenType math font Cambria, but it is useful enough to be added.

Note 9: `FractionDelimiterDisplayStyleSize` and `FractionDelimiterSize` do not actually exist in the 'standard' OpenType math font Cambria, but were useful enough to be added.

7.5 Math spacing

7.5.1 Inline surrounding space

Inline math is surrounded by (optional) `\mathsurround` spacing but that is a fixed dimension. There is now an additional parameter `\mathsurroundskip`. When set to a non-zero value (or zero with some stretch or shrink) this parameter will replace `\mathsurround`. By using an additional parameter instead of changing the nature of `\mathsurround`, we can remain compatible. In the meantime a bit more control has been added via `\mathsurroundmode`. This directive can take 6 values with zero being the default behaviour.

```
\mathsurround 10pt
\mathsurroundskip20pt
```

| MODE | X\$X\$X | X \$X\$ X | EFFECT |
|------|---------|-----------|--|
| 0 | xxx | x x x | obey <code>\mathsurround</code> when <code>\mathsurroundskip</code> is 0pt |
| 1 | xxx | x x x | only add skip to the left |
| 2 | xxx | x x x | only add skip to the right |
| 3 | xxx | x x x | add skip to the left and right |
| 4 | xxx | x x x | ignore the skip setting, obey <code>\mathsurround</code> |
| 5 | xxx | x x x | disable all spacing around math |
| 6 | xxx | x x x | only apply <code>\mathsurroundskip</code> when also spacing |
| 7 | xxx | x x x | only apply <code>\mathsurroundskip</code> when no spacing |

Method six omits the surround glue when there is (x)spacing glue present while method seven does the opposite, the glue is only applied when there is (x)space glue present too. Anything more fancy, like checking the beginning or end of a paragraph (or edges of a box) would not be robust anyway. If you want that you can write a callback that runs over a list and analyzes a paragraph. Actually, in that case you could also inject glue (or set the properties of a math node) explicitly. So, these modes are in practice mostly useful for special purposes and experiments



(they originate in a tracker item). Keep in mind that this glue is part of the math node and not always treated as normal glue: it travels with the begin and end math nodes. Also, method 6 and 7 will zero the skip related fields in a node when applicable in the first occasion that checks them (linebreaking or packaging).

7.5.2 Pairwise spacing

Besides the parameters mentioned in the previous sections, there are also 64 new primitives to control the math spacing table (as explained in Chapter 18 of the \TeX book). The primitive names are a simple matter of combining two math atom types, but for completeness' sake, here is the whole list:

| | |
|------------------------------------|--------------------------------------|
| <code>\Umathordordspacing</code> | <code>\Umathopenordspacing</code> |
| <code>\Umathordopspacing</code> | <code>\Umathopenopspacing</code> |
| <code>\Umathordbinspacing</code> | <code>\Umathopenbinspacing</code> |
| <code>\Umathordrelspacing</code> | <code>\Umathopenrelspacing</code> |
| <code>\Umathordopenspacing</code> | <code>\Umathopenopenspacing</code> |
| <code>\Umathordclosespacing</code> | <code>\Umathopenclosespacing</code> |
| <code>\Umathordpunctspacing</code> | <code>\Umathopenpunctspacing</code> |
| <code>\Umathordinnerspacing</code> | <code>\Umathopeninnerspacing</code> |
| <code>\Umathopordspacing</code> | <code>\Umathcloseordspacing</code> |
| <code>\Umathopopspacing</code> | <code>\Umathcloseopspacing</code> |
| <code>\Umathopbinspacing</code> | <code>\Umathclosebinspacing</code> |
| <code>\Umathoprelspacing</code> | <code>\Umathclosere-spacing</code> |
| <code>\Umathopopenspacing</code> | <code>\Umathcloseopenspacing</code> |
| <code>\Umathopclosespacing</code> | <code>\Umathcloseclosespacing</code> |
| <code>\Umathoppunctspacing</code> | <code>\Umathclosepunctspacing</code> |
| <code>\Umathopinnerspacing</code> | <code>\Umathcloseinnerspacing</code> |
| <code>\Umathbinordspacing</code> | <code>\Umathpunctordspacing</code> |
| <code>\Umathbinopspacing</code> | <code>\Umathpunctopspacing</code> |
| <code>\Umathbinbinspacing</code> | <code>\Umathpunctbinspacing</code> |
| <code>\Umathbinrelspacing</code> | <code>\Umathpunctrelspacing</code> |
| <code>\Umathbinopenspacing</code> | <code>\Umathpunctopenspacing</code> |
| <code>\Umathbinclosespacing</code> | <code>\Umathpunctclosespacing</code> |
| <code>\Umathbinpunctspacing</code> | <code>\Umathpunctpunctspacing</code> |
| <code>\Umathbininnerspacing</code> | <code>\Umathpunctinnerspacing</code> |
| <code>\Umathrelordspacing</code> | <code>\Umathinnerordspacing</code> |
| <code>\Umathrelopspacing</code> | <code>\Umathinneropspacing</code> |
| <code>\Umathrelbinspacing</code> | <code>\Umathinnerbinspacing</code> |
| <code>\Umathrelrelspacing</code> | <code>\Umathinnerrelspacing</code> |
| <code>\Umathrelopenspacing</code> | <code>\Umathinneropenspacing</code> |
| <code>\Umathrelclosespacing</code> | <code>\Umathinnerclosespacing</code> |
| <code>\Umathrelpunctspacing</code> | <code>\Umathinnerpunctspacing</code> |
| <code>\Umathrelinnerspacing</code> | <code>\Umathinnerinnerspacing</code> |

These parameters are of type `\muskip`, so setting a parameter can be done like this:



`\Umathopordspacing\displaystyle=4mu plus 2mu`

They are all initialized by `initex` to the values mentioned in the table in Chapter 18 of the `TEXbook`.

Note 1: for ease of use as well as for backward compatibility, `\thinmuskip`, `\medmuskip` and `\thickmuskip` are treated specially. In their case a pointer to the corresponding internal parameter is saved, not the actual `\muskip` value. This means that any later changes to one of these three parameters will be taken into account.

Note 2: Careful readers will realise that there are also primitives for the items marked * in the `TEXbook`. These will not actually be used as those combinations of atoms cannot actually happen, but it seemed better not to break orthogonality. They are initialized to zero.

7.5.3 Skips around display math

The injection of `\abovedisplayskip` and `\belowdisplayskip` is not symmetrical. An above one is always inserted, also when zero, but the below is only inserted when larger than zero. Especially the latter makes it sometimes hard to fully control spacing. Therefore `LuaTEX` comes with a new directive: `\mathdisplayskipmode`. The following values apply:

| VALUE | MEANING |
|-------|--|
| 0 | normal <code>T_EX</code> behaviour |
| 1 | always (same as 0) |
| 2 | only when not zero |
| 3 | never, not even when not zero |

By default the short skip detection is not adapted to `r2l` typesetting and that hasn't been the case since the start of the project. Changing it could break hacks that users came up with but when you set `\matheqdirmode` to a positive value direction will be taken into account.

7.5.4 Nolimit correction

There are two extra math parameters `\Umathnolimitsupfactor` and `\Umathnolimitsubfactor` that were added to provide some control over how limits are spaced (for example the position of super and subscripts after integral operators). They relate to an extra parameter `\mathnolimitsmode`. The half corrections are what happens when scripts are placed above and below. The problem with italic corrections is that officially that correction italic is used for above/below placement while advanced kerns are used for placement at the right end. The question is: how often is this implemented, and if so, do the kerns assume correction too. Anyway, with this parameter one can control it.

| | \int_1^0 | \int_1^0 | \int_1^0 | \int_1^0 | \int_1^0 | \int_1^0 |
|--------------------|------------|------------|------------|------------|------------|-------------|
| mode | 0 | 1 | 2 | 3 | 4 | 8000 |
| superscript | 0 | font | 0 | 0 | +ic/2 | 0 |
| subscript | -ic | font | 0 | -ic/2 | -ic/2 | 8000ic/1000 |



When the mode is set to one, the math parameters are used. This way a macro package writer can decide what looks best. Given the current state of fonts in ConTeXt we currently use mode 1 with factor 0 for the superscript and 750 for the subscripts. Positive values are used for both parameters but the subscript shifts to the left. A `\mathnolimitsmode` larger than 15 is considered to be a factor for the subscript correction. This feature can be handy when experimenting.

7.5.5 Math italic mess

The `\mathitalicsmode` parameter can be set to 1 to force italic correction before noads that represent some more complex structure (read: everything that is not an ord, bin, rel, open, close, punct or inner). A value of 2 will enforce the old school font code path for all italics. We show a Cambria example.

```
\mathitalicsmode = 0  $T^1$   $T$   $T+1$   $T\frac{1}{2}$   $T\sqrt{1}$ 
\mathitalicsmode = 1  $T^1$   $T$   $T+1$   $T\frac{1}{2}$   $T\sqrt{1}$ 
```

This kind of parameters relate to the fact that italic correction in OpenType math is bound to fuzzy rules. So, control is the solution.

7.5.6 Script and kerning

If you want to typeset text in math macro packages often provide something `\text` which obeys the script sizes. As the definition can be anything there is a good chance that the kerning doesn't come out well when used in a script. Given that the first glyph ends up in a `\hbox` we have some control over this. And, as a bonus we also added control over the normal sublist kerning. The `\mathscriptboxmode` parameter defaults to 1.

| VALUE | MEANING |
|-------|---|
| 0 | forget about kerning |
| 1 | kern math sub lists with a valid glyph |
| 2 | also kern math sub boxes that have a valid glyph |
| 2 | only kern math sub boxes with a boundary node present |

Here we show some examples. Of course this doesn't solve all our problems, if only because some fonts have characters with bounding boxes that compensate for italics, while other fonts can lack kerns.

| | <code>\$T_{\text{fluff}}\$</code> | <code>\$T_{\text{fluff}}\$</code> | <code>\$T_{\text{fluff}}\$</code> | <code>\$T_{\text{fluff}}\$</code> | <code>\$T_{\text{fluff}}\$</code> |
|----------|-----------------------------------|--------------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| | mode 0 | mode 1 | mode 1 | mode 2 | mode 3 |
| modern | T_{fluff} | T_{fluff} ^{-1.479} | T_{fluff} | T_{fluff} | T_{fluff} |
| lucidaot | T_{fluff} | T_{fluff} ^{-1.389} | T_{fluff} | T_{fluff} | T_{fluff} |
| pagella | T_{fluff} | T_{fluff} ^{-1.530} | T_{fluff} | T_{fluff} | T_{fluff} |
| cambria | T_{fluff} | T_{fluff} ^{-1.367} | T_{fluff} | T_{fluff} | T_{fluff} |
| dejavu | T_{fluff} | T_{fluff} | T_{fluff} | T_{fluff} | T_{fluff} |

Kerning between a character subscript is controlled by `\mathscriptcharm` which also defaults to 1.



Here is another example. Internally we tag kerns as italic kerns or font kerns where font kerns result from the staircase kern tables. In 2018 fonts like Latin Modern and Pagella rely on cheats with the boundingbox, Cambria uses staircase kerns and Lucida a mixture. Depending on how fonts evolve we might add some more control over what one can turn on and off.

| | | | | | |
|--------|----------|-------------------------|------------------------------|--|-------------------------------|
| normal | modern | T_f ^{-2.561} | γ_e ^{-0.917} | γ_{ee} ^{-0.917} | T_{fluff} ^{-2.561} |
| | pagella | T_f ^{-3.703} | γ_e ^{-0.796} | γ_{ee} ^{-0.796} | T_{fluff} ^{-0.900} |
| | cambria | T_f ^{-2.367} | γ_e ^{-1.657} | γ_{ee} ^{-1.657} ^{1.982} | T_{fluff} ^{-2.367} |
| | lucidaot | T_f ^{-2.405} | γ_e ^{-1.107} | γ_{ee} ^{-1.107} | T_{fluff} ^{-2.405} |
| bold | modern | T_f ^{-2.945} | γ_e ^{-1.055} | γ_{ee} ^{-1.055} | T_{fluff} ^{-2.945} |
| | pagella | T_f ^{-3.838} | γ_e ^{-0.915} | γ_{ee} ^{-0.915} | T_{fluff} ^{-1.035} |
| | cambria | T_f ^{-2.331} | γ_e ^{-1.632} | γ_{ee} ^{-1.632} ^{0.440} | T_{fluff} ^{-2.331} |
| | lucidaot | T_f ^{-2.329} | γ_e ^{-1.091} | γ_{ee} ^{-1.091} | T_{fluff} ^{-1.933} |

7.5.7 Fixed scripts

We have three parameters that are used for this fixed anchoring:

| PARAMETER | REGISTER |
|-----------|------------------------------------|
| d | <code>\Umathsubshiftdown</code> |
| u | <code>\Umathsupshiftp</code> |
| s | <code>\Umathsubsupshiftdown</code> |

When we set `\mathscriptsmode` to a value other than zero these are used for calculating fixed positions. This is something that is needed for instance for chemistry. You can manipulate the mentioned variables to achieve different effects.

| MODE | DOWN | UP | EXAMPLE |
|------|-----------------|-----------------|---|
| 0 | dynamic | dynamic | $\text{CH}_2 + \text{CH}_2^+ + \text{CH}_2^2$ |
| 1 | d | u | $\text{CH}_2 + \text{CH}_2^+ + \text{CH}_2^2$ |
| 2 | s | u | $\text{CH}_2 + \text{CH}_2^+ + \text{CH}_2^2$ |
| 3 | s | $u + s - d$ | $\text{CH}_2 + \text{CH}_2^+ + \text{CH}_2^2$ |
| 4 | $d + (s - d)/2$ | $u + (s - d)/2$ | $\text{CH}_2 + \text{CH}_2^+ + \text{CH}_2^2$ |
| 5 | d | $u + s - d$ | $\text{CH}_2 + \text{CH}_2^+ + \text{CH}_2^2$ |

The value of this parameter obeys grouping but applies to the whole current formula.

7.5.8 Penalties: `\mathpenaltiesmode`

Only in inline math penalties will be added in a math list. You can force penalties (also in display math) by setting:

```
\mathpenaltiesmode = 1
```



This primitive is not really needed in Lua \TeX because you can use the callback `mlist_to_hlist` to force penalties by just calling the regular routine with forced penalties. However, as part of opening up and control this primitive makes sense. As a bonus we also provide two extra penalties:

```
\prebinoppenalty = -100 % example value
\prerelpenalty   =  900 % example value
```

They default to infinite which signals that they don't need to be inserted. When set they are injected before a binop or rel node. This is an experimental feature.

7.5.9 Equation spacing: `\matheqnogapstep`

By default \TeX will add one quad between the equation and the number. This is hard coded. A new primitive can control this:

```
\matheqnogapstep = 1000
```

Because a math quad from the math text font is used instead of a dimension, we use a step to control the size. A value of zero will suppress the gap. The step is divided by 1000 which is the usual way to mimick floating point factors in \TeX .

7.6 Math constructs

7.6.1 Unscaled fences

The `\mathdelimitersmode` primitive is experimental and deals with the following (potential) problems. Three bits can be set. The first bit prevents an unwanted shift when the fence symbol is not scaled (a cambria side effect). The second bit forces italic correction between a preceding character ordinal and the fenced subformula, while the third bit turns that subformula into an ordinary so that the same spacing applies as with unfenced variants. Here we show Cambria (with `\mathitalicsmode` enabled).

```
\mathdelimitersmode = 0  $f(x)$   $f(x)$ 
\mathdelimitersmode = 1  $f(x)$   $f(x)$ 
\mathdelimitersmode = 2  $f(x)$   $f(x)$ 
\mathdelimitersmode = 3  $f(x)$   $f(x)$ 
\mathdelimitersmode = 4  $f(x)$   $f(x)$ 
\mathdelimitersmode = 5  $f(x)$   $f(x)$ 
\mathdelimitersmode = 6  $f(x)$   $f(x)$ 
\mathdelimitersmode = 7  $f(x)$   $f(x)$ 
```

So, when set to 7 fenced subformulas with unscaled delimiters come out the same as unfenced ones. This can be handy for cases where one is forced to use `\left` and `\right` always because of unpredictable content. As said, it's an experimental feature (which somehow fits in the exceptional way fences are dealt with in the engine). The full list of flags is given in the next table:



| VALUE | MEANING |
|-------|---------------------------------------|
| "01 | don't apply the usual shift |
| "02 | apply italic correction when possible |
| "04 | force an ordinary subformula |
| "08 | no shift when a base character |
| "10 | only shift when an extensible |

The effect can depend on the font (and for Cambria one can use for instance "16).

7.6.2 Accent handling

Lua \TeX supports both top accents and bottom accents in math mode, and math accents stretch automatically (if this is supported by the font the accent comes from, of course). Bottom and combined accents as well as fixed-width math accents are controlled by optional keywords following `\Umathaccent`.

The keyword `bottom` after `\Umathaccent` signals that a bottom accent is needed, and the keyword `both` signals that both a top and a bottom accent are needed (in this case two accents need to be specified, of course).

Then the set of three integers defining the accent is read. This set of integers can be prefixed by the `fixed` keyword to indicate that a non-stretching variant is requested (in case of both accents, this step is repeated).

A simple example:

```
\Umathaccent both fixed 0 0 "20D7 fixed 0 0 "20D7 {example}
```

If a math top accent has to be placed and the accentee is a character and has a non-zero `top_accent` value, then this value will be used to place the accent instead of the `\skewchar` kern used by \TeX 82.

The `top_accent` value represents a vertical line somewhere in the accentee. The accent will be shifted horizontally such that its own `top_accent` line coincides with the one from the accentee. If the `top_accent` value of the accent is zero, then half the width of the accent followed by its italic correction is used instead.

The vertical placement of a top accent depends on the `x_height` of the font of the accentee (as explained in the \TeX book), but if a value turns out to be zero and the font had a `MathConstants` table, then `AccentBaseHeight` is used instead.

The vertical placement of a bottom accent is straight below the accentee, no correction takes place.

Possible locations are `top`, `bottom`, `both` and `center`. When no location is given `top` is assumed. An additional parameter `fraction` can be specified followed by a number; a value of for instance 1200 means that the criterium is 1.2 times the width of the nucleus. The `fraction` only applies to the stepwise selected shapes and is mostly meant for the `overlay` location. It also works for the other locations but then it concerns the width.



7.6.3 Radical extensions

The new primitive `\Uroot` allows the construction of a radical noad including a degree field. Its syntax is an extension of `\Uradical`:

```
\Uradical <fam integer> <char integer> <radicand>
\Uroot    <fam integer> <char integer> <degree> <radicand>
```

The placement of the degree is controlled by the math parameters `\Umathradicaldegreebefore`, `\Umathradicaldegreeafter`, and `\Umathradicaldegreeraise`. The degree will be typeset in `\scriptscriptstyle`.

7.6.4 Super- and subscripts

The character fields in a Lua-loaded OpenType math font can have a ‘mathkern’ table. The format of this table is the same as the ‘mathkern’ table that is returned by the `fontloader` library, except that all height and kern values have to be specified in actual scaled points.

When a super- or subscript has to be placed next to a math item, Lua \TeX checks whether the super- or subscript and the nucleus are both simple character items. If they are, and if the fonts of both character items are OpenType fonts (as opposed to legacy \TeX fonts), then Lua \TeX will use the OpenType math algorithm for deciding on the horizontal placement of the super- or subscript.

This works as follows:

- ▶ The vertical position of the script is calculated.
- ▶ The default horizontal position is flat next to the base character.
- ▶ For superscripts, the italic correction of the base character is added.
- ▶ For a superscript, two vertical values are calculated: the bottom of the script (after shifting up), and the top of the base. For a subscript, the two values are the top of the (shifted down) script, and the bottom of the base.
- ▶ For each of these two locations:
 - find the math kern value at this height for the base (for a subscript placement, this is the `bottom_right` corner, for a superscript placement the `top_right` corner)
 - find the math kern value at this height for the script (for a subscript placement, this is the `top_left` corner, for a superscript placement the `bottom_left` corner)
 - add the found values together to get a preliminary result.
- ▶ The horizontal kern to be applied is the smallest of the two results from previous step.

The math kern value at a specific height is the kern value that is specified by the next higher height and kern pair, or the highest one in the character (if there is no value high enough in the character), or simply zero (if the character has no math kern pairs at all).

7.6.5 Scripts on extensibles

The primitives `\Underdelimiter` and `\Overdelimiter` allow the placement of a subscript or superscript on an automatically extensible item and `\Udelimiterunder` and `\Udelimiterover`



allow the placement of an automatically extensible item as a subscript or superscript on a nucleus. The input:

```

 $\Uoverdelimiterr$  0 "2194  $\{\hbox{\strut overdelimiterr}\}$ $
 $\Uunderdelimiterr$  0 "2194  $\{\hbox{\strut underdelimiterr}\}$ $
 $\Udelimiterr$ over 0 "2194  $\{\hbox{\strut delimiterr}over\}$ $
 $\Udelimiterr$ under 0 "2194  $\{\hbox{\strut delimiterr}under\}$ $

```

will render this:

$$\begin{array}{ccccccc}
 \overdelimiterr & & & & \overdelimiterr & & \\
 \leftarrow & \leftarrow & \leftarrow & \leftarrow & \leftarrow & \leftarrow & \\
 & \underdelimiterr & & & delimiterr & delimiterr & \\
 & & & & \underdelimiterr & &
 \end{array}$$

The vertical placements are controlled by `\Umathunderdelimiterrbgap`, `\Umathunderdelimiterrvgap`, `\Umathoverdelimiterrbgap`, and `\Umathoverdelimiterrvgap` in a similar way as limit placements on large operators. The superscript in `\Uoverdelimiterr` is typeset in a suitable scripted style, the subscript in `\Uunderdelimiterr` is cramped as well.

These primitives accepts an option `width` specification. When used the also optional keywords `left`, `middle` and `right` will determine what happens when a requested size can't be met (which can happen when we step to successive larger variants).

An extra primitive `\Uhextextensible` is available that can be used like this:

```

 $\Uhextextensible$  width 10cm 0 "2194$

```

This will render this:

$$\longleftrightarrow$$

Here you can also pass options, like:

```

 $\Uhextextensible$  width 1pt middle 0 "2194$

```

This gives:

$$\leftrightarrow$$

Lua \TeX internally uses a structure that supports OpenType 'MathVariants' as well as tfm 'extensible recipes'. In most cases where font metrics are involved we have a different code path for traditional fonts end OpenType fonts.

Sometimes you might want to act upon the size of a delimiter, something that is not really possible because of the fact that they are calculated *after* most has been typeset already. In the following example the all-zero specification is the trigger to make a fake box with the last delimiter dimensions and shift. It's an ugly hack but its relative simple and not intrusive implementation has no side effects. Any other heuristic solution would not satisfy possible demands anyway. Here is a rather low level example:

```

\startformula
\Uleft \Udelimiterr 5 0 "222B
\frac{\frac{a}{b}}{\frac{c}{d}}

```



```

\Uright \Udelimiter 5 0 "222B
\kern-2\fontcharwd\textfont0 "222B
\mathlimop{\Uvextensible \Udelimiter 0 0 0}_1^2 x
\stopformula

```

The last line, by passing zero values, results in a fake operator that has the dimensions of the previous delimiter. We can then backtrack over the (presumed) width and the two numbers become limit operators. As said, it's not pretty but it works.

7.6.6 Fractions

The `\abovewithdelims` command accepts a keyword `exact`. When issued the extra space relative to the rule thickness is not added. One can of course use the `\Umathfraction.gap` commands to influence the spacing. Also the rule is still positioned around the math axis.

```

$$ { {a} \abovewithdelims() exact 4pt {b} } $$

```

The math parameter table contains some parameters that specify a horizontal and vertical gap for skewed fractions. Of course some guessing is needed in order to implement something that uses them. And so we now provide a primitive similar to the other fraction related ones but with a few options so that one can influence the rendering. Of course a user can also mess around a bit with the parameters `\Umathskewedfractionhgap` and `\Umathskewedfractionvgap`.

The syntax used here is:

```

{ {1} \Uskewed / <options> {2} }
{ {1} \Uskewedwithdelims / () <options> {2} }

```

where the options can be `noaxis` and `exact`. By default we add half the axis to the shifts and by default we zero the width of the middle character. For Latin Modern the result looks as follows:

| | | | | |
|---------------------------|-----------------------|-----------------------|------------------------------------|------------------------------------|
| | $x + \frac{a}{b} + x$ | $x + \frac{1}{2} + x$ | $x + \left(\frac{a}{b}\right) + x$ | $x + \left(\frac{1}{2}\right) + x$ |
| <code>exact</code> | $x + \frac{a}{b} + x$ | $x + \frac{1}{2} + x$ | $x + \left(\frac{a}{b}\right) + x$ | $x + \left(\frac{1}{2}\right) + x$ |
| <code>noaxis</code> | $x + \frac{a}{b} + x$ | $x + \frac{1}{2} + x$ | $x + \left(\frac{a}{b}\right) + x$ | $x + \left(\frac{1}{2}\right) + x$ |
| <code>exact noaxis</code> | $x + \frac{a}{b} + x$ | $x + \frac{1}{2} + x$ | $x + \left(\frac{a}{b}\right) + x$ | $x + \left(\frac{1}{2}\right) + x$ |

The keyword `norule` will hide the rule with the above variants while keeping the rule related spacing.

7.6.7 Delimiters: `\Uleft`, `\Umiddle` and `\Uright`

Normally you will force delimiters to certain sizes by putting an empty box or rule next to it. The resulting delimiter will either be a character from the stepwise size range or an extensible. The latter can be quite differently positioned than the characters as it depends on the fit as well as the fact if the used characters in the font have depth or height. Commands like (plain T_EXs) `\big` need use this feature. In LuaT_EX we provide a bit more control by three variants that support optional parameters `height`, `depth` and `axis`. The following example uses this:

```

\Uleft height 30pt depth 10pt \Udelimiter "0 "0 "000028
\quad x\quad

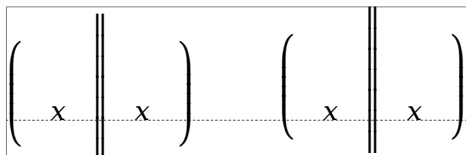
```



```

\Umiddle height 40pt depth 15pt      \Udelimiter "0 "0 "002016
\quad x\quad
\Uright height 30pt depth 10pt      \Udelimiter "0 "0 "000029
\quad \quad \quad
\Uleft height 30pt depth 10pt axis \Udelimiter "0 "0 "000028
\quad x\quad
\Umiddle height 40pt depth 15pt axis \Udelimiter "0 "0 "002016
\quad x\quad
\Uright height 30pt depth 10pt axis \Udelimiter "0 "0 "000029

```



The keyword `exact` can be used as directive that the real dimensions should be applied when the criteria can't be met which can happen when we're still stepping through the successively larger variants. When no dimensions are given the `noaxis` command can be used to prevent shifting over the axis.

You can influence the final class with the keyword `class` which will influence the spacing. The numbers are the same as for character classes.

7.7 Extracting values

7.7.1 Codes

You can extract the components of a math character. Say that we have defined:

```
\Umathcode 1 2 3 4
```

then

```
[\Umathcharclass1] [\Umathcharfam1] [\Umathcharslot1]
```

will return:

```
[2] [3] [4]
```

These commands are provided as convenience. Before they come available you could do the following:

```

\def\Umathcharclass{\directlua{tex.print(tex.getmathcode(token.scan_int())[1])}}
\def\Umathcharfam  {\directlua{tex.print(tex.getmathcode(token.scan_int())[2])}}
\def\Umathcharslot {\directlua{tex.print(tex.getmathcode(token.scan_int())[3])}}

```

7.7.2 Last lines

There is a new primitive to control the overshoot in the calculation of the previous line in mid-paragraph display math. The default value is 2 times the em width of the current font:



```
\predisplayspacefactor=2000
```

If you want to have the length of the last line independent of math i.e. you don't want to revert to a hack where you insert a fake display math formula in order to get the length of the last line, the following will often work too:

```
\def\lastlinelength{\dimexpr
  \directlua {tex.sprint (
    (nodes.dimensions(node.tail(tex.lists.page_head).list))
  )}sp
\relax}
```

7.8 Math mode

7.8.1 Verbose versions of single-character math commands

LuaTeX defines six new primitives that have the same function as \wedge , $_$, $\$$, and $\$\$$:

| PRIMITIVE | EXPLANATION |
|---------------------------------|--|
| <code>\Usuperscript</code> | duplicates the functionality of \wedge |
| <code>\Usubscript</code> | duplicates the functionality of $_$ |
| <code>\Ustartmath</code> | duplicates the functionality of $\$$, when used in non-math mode. |
| <code>\Ustopmath</code> | duplicates the functionality of $\$$, when used in inline math mode. |
| <code>\Ustartdisplaymath</code> | duplicates the functionality of $\$\$$, when used in non-math mode. |
| <code>\Ustopdisplaymath</code> | duplicates the functionality of $\$\$$, when used in display math mode. |

The `\Ustopmath` and `\Ustopdisplaymath` primitives check if the current math mode is the correct one (inline vs. displayed), but you can freely intermix the four `mathon/mathoff` commands with explicit dollar sign(s).

7.8.2 Script commands `\Unosuperscript` and `\Unosubscript`

These two commands result in super- and subscripts but with the current style (at the time of rendering). So,

```
$
  x\Unosuperscript {1}\Unosubscript {2} =
  x\Unosuperscript{1}\Unosubscript{2} =
  x\Unosuperscript {1}\Unosubscript{2} =
  x\Unosuperscript{1}\Unosubscript {2}
$
```

results in $x_2^1 = x_2^1 = x_2^1 = x_2^1$.



7.8.3 Allowed math commands in non-math modes

The commands `\mathchar`, and `\Umathchar` and control sequences that are the result of `\mathchardef` or `\Umathchardef` are also acceptable in the horizontal and vertical modes. In those cases, the `\textfont` from the requested math family is used.

7.9 Goodies

7.9.1 Flattening: `\mathflattenmode`

The \TeX math engine collapses ord noads without sub- and superscripts and a character as nucleus. and which has the side effect that in OpenType mode italic corrections are applied (given that they are enabled).

```
\switchtobodyfont[modern]
$V \mathbin{\mathbin{v}} V$\par
$V \mathord{\mathord{v}} V$\par
```

This renders as:

$V v V$
 VvV

When we set `\mathflattenmode` to 31 we get:

$V v V$
 VvV

When you see no difference, then the font probably has the proper character dimensions and no italic correction is needed. For Latin Modern (at least till 2018) there was a visual difference. In that respect this parameter is not always needed unless of course you want efficient math lists anyway.

You can influence flattening by adding the appropriate number to the value of the mode parameter. The default value is 1.

| MODE | CLASS |
|------|-------|
| 1 | ord |
| 2 | bin |
| 4 | rel |
| 8 | punct |
| 16 | inner |

7.9.2 Less Tracing

Because there are quite some math related parameters and values, it is possible to limit tracing. Only when `tracingassigns` and/or `tracingrestores` are set to 2 or more they will be traced.



7.9.3 Math options with `\mathdefaultsmode`

This option has been introduced because L^AT_EX developers wanted some of the defaults to be different from the ones that were set in stone when we froze LuaT_EX. The default values are:

| | SCANNING | RENDERING |
|-----------------|----------|-----------|
| radical/root | cramped | cramped |
| under delimiter | cramped | supstyle |
| over delimiter | cramped | substyle |
| delimiter under | cramped | current |
| delimiter over | cramped | current |

When `\mathdefaultsmode` is larger than zero, we have:

| | SCANNING | RENDERING |
|-----------------|----------|-----------|
| radical/root | cramped | cramped |
| under delimiter | substyle | substyle |
| over delimiter | supstyle | supstyle |
| delimiter under | current | current |
| delimiter over | cramped | cramped |

It is outside the scope of this manual to discuss the rationale behind these defaults. The zero values date back from the early times. If needed you can explicitly set the style in the content argument.

7.9.4 Math options with `\mathoption`

The logic in the math engine is rather complex and there are often no universal solutions (read: what works out well for one font, fails for another). Therefore some variations in the implementation are driven by parameters (modes). In addition there is a new primitive `\mathoption` which will be used for testing. Don't rely on any option to be there in a production version as they are meant for development.

This option was introduced for testing purposes when the math engine got split code paths and it forces the engine to treat new fonts as old ones with respect to italic correction etc. There are no guarantees given with respect to the final result and unexpected side effects are not seen as bugs as they relate to font properties. There is currently only one option:

The `oldmath` boolean flag in the Lua font table is the official way to force old treatment as it's bound to fonts. Like with all options we may temporarily introduce with this command this feature is not meant for production.



8 Nodes

8.1 LUA node representation

\TeX 's nodes are represented in Lua as userdata objects with a variable set of fields. In the following syntax tables, such as 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), `boundary` (6), `disc` (7), `whatsit` (8), `local_par` (9), `dir` (10), `math` (11), `glue` (12), `kern` (13), `penalty` (14), `unset` (15), `style` (16), `choice` (17), `noad` (18), `radical` (19), `fraction` (20), `accent` (21), `fence` (22), `math_char` (23), `sub_box` (24), `sub_mlist` (25), `math_text_char` (26), `delim` (27), `margin_kern` (28), `glyph` (29), `align_record` (30), `pseudo_file` (31), `pseudo_line` (32), `page_insert` (33), `split_insert` (34), `expr_stack` (35), `nested_list` (36), `span` (37), `attribute` (38), `glue_spec` (39), `attribute_list` (40), `temp` (41), `align_stack` (42), `movement_stack` (43), `if_stack` (44), `unhyphenated` (45), `hyphenated` (46), `delta` (47), `passive` (48), `shape` (49).

The `\lastnodetype` primitive is ε - \TeX compliant. The valid range is still $[-1, 15]$ and `glyph` nodes (formerly known as `char` nodes) have number 0 while ligature nodes are mapped to 7. That way macro packages can use the same symbolic names as in traditional ε - \TeX . Keep in mind that these ε - \TeX node numbers are different from the real internal ones and that there are more ε - \TeX node types than 15.

You can ask for a list of fields with `node.fields` and for valid subtypes with `node.subtypes`. The `node.values` function reports some used values. Valid arguments are `dir`, `direction`, `glue`, `pdf_literal`, `pdf_action`, `pdf_window` and `color_stack`. Keep in mind that the setters normally expect a number, but this helper gives you a list of what numbers matter. For practical reason the `pagestate` values are also reported with this helper.

8.2 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 |
|----------------------|---------------------|--|
| <code>next</code> | <code>node</code> | the next node in a list, or <code>nil</code> |
| <code>id</code> | <code>number</code> | the node's type (<code>id</code>) number |
| <code>subtype</code> | <code>number</code> | the node subtype identifier |

The `subtype` is sometimes just a dummy entry because 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 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. By now most of \TeX 's node processing makes sure that the `prev` nodes are



valid but there can be exceptions, especially when the internal magic uses a leading temp nodes to temporarily store a state.

8.2.1 hlist nodes

| FIELD | TYPE | EXPLANATION |
|------------|--------|--|
| subtype | number | 0 = unknown, 1 = line, 2 = box, 3 = indent, 4 = alignment, 5 = cell, 6 = equation, 7 = equationnumber, 8 = math, 9 = mathchar, 10 = hex-tensible, 11 = vextensible, 12 = hdelimiter, 13 = vdelimiter, 14 = overdelimiter, 15 = underdelimiter, 16 = numerator, 17 = denominator, 18 = limits, 19 = fraction, 20 = nucleus, 21 = sup, 22 = sub, 23 = degree, 24 = scripts, 25 = over, 26 = under, 27 = accent, 28 = radical |
| attr | node | list of attributes |
| width | number | the width of the box |
| height | number | the height of the box |
| depth | number | the depth of the box |
| 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 | 0 = normal, 1 = stretching, 2 = shrinking |
| head/list | node | the first node of the body of this list |
| dir | string | the direction of this box, see 8.2.15 |

A warning: never assign a node list to the head field unless you are sure its internal link structure is correct, otherwise an error may result.

Note: the field name head and list are both valid. Sometimes it makes more sense to refer to a list by head, sometimes list makes more sense.

8.2.2 vlist nodes

This node is similar to hlist, except that 'shift' is a displacement perpendicular to the line progression direction, and 'subtype' only has the values 0, 4, and 5.

8.2.3 rule nodes

Contrary to traditional T_EX, LuaT_EX has more \rule subtypes because we also use rules to store reuseable objects and images. User nodes are invisible and can be intercepted by a callback.

| FIELD | TYPE | EXPLANATION |
|---------|--------|--|
| subtype | number | 0 = normal, 1 = box, 2 = image, 3 = empty, 4 = user, 5 = over, 6 = under, 7 = fraction, 8 = radical, 9 = outline |
| attr | node | list of attributes |
| width | number | the width of the rule where the special value -1073741824 is used for 'running' glue dimensions |



| | | |
|-----------|--------|--|
| height | number | the height of the rule (can be negative) |
| depth | number | the depth of the rule (can be negative) |
| left | number | shift at the left end (also subtracted from width) |
| right | number | (subtracted from width) |
| dir | string | the direction of this rule, see 8.2.15 |
| index | number | an optional index that can be referred to |
| transform | number | an private variable (also used to specify outline width) |

The `left` and `right` keys are somewhat special (and experimental). When rules are auto adapting to the surrounding box width you can enforce a shift to the right by setting `left`. The value is also subtracted from the width which can be a value set by the engine itself and is not entirely under user control. The `right` is also subtracted from the width. It all happens in the backend so these are not affecting the calculations in the frontend (actually the auto settings also happen in the backend). For a vertical rule `left` affects the height and `right` affects the depth. There is no matching interface at the \TeX end (although we can have more keywords for rules it would complicate matters and introduce a speed penalty.) However, you can just construct a rule node with Lua and write it to the \TeX input. The `outline` subtype is just a convenient variant and the `transform` field specifies the width of the outline.

8.2.4 ins nodes

This node relates to the `\insert` primitive.

| FIELD | TYPE | EXPLANATION |
|-----------|--------|---|
| subtype | number | the insertion class |
| attr | node | list of attributes |
| cost | number | the penalty associated with this insert |
| height | number | height of the insert |
| depth | number | depth of the insert |
| head/list | node | the first node of the body of this insert |

There is a set of extra fields that concern the associated glue: `width`, `stretch`, `stretch_order`, `shrink` and `shrink_order`. These are all numbers.

A warning: never assign a node list to the `head` field unless you are sure its internal link structure is correct, otherwise an error may result. You can use `list` instead (often in functions you want to use local variable with similar names and both names are equally sensible).

8.2.5 mark nodes

This one relates to the `\mark` primitive.

| FIELD | TYPE | EXPLANATION |
|---------|--------|-----------------------------------|
| subtype | number | unused |
| attr | node | list of attributes |
| class | number | the mark class |
| mark | table | a table representing a token list |



8.2.6 adjust nodes

This node comes from `\vadjust` primitive.

| FIELD | TYPE | EXPLANATION |
|-----------|--------|---------------------|
| subtype | number | 0 = normal, 1 = pre |
| attr | node | list of attributes |
| head/list | node | adjusted material |

A warning: never assign a node list to the head field unless you are sure its internal link structure is correct, otherwise an error may be the result.

8.2.7 disc nodes

The `\discretionary` and `\-`, the - character but also the hyphenation mechanism produces these nodes.

| FIELD | TYPE | EXPLANATION |
|---------|--------|--|
| subtype | number | 0 = discretionary, 1 = explicit, 2 = automatic, 3 = regular, 4 = first, 5 = second |
| attr | node | list of attributes |
| pre | node | pointer to the pre-break text |
| post | node | pointer to the post-break text |
| replace | node | pointer to the no-break text |
| penalty | number | the penalty associated with the break, normally <code>\hyphenpenalty</code> or <code>\exhyphenpenalty</code> |

The subtype numbers 4 and 5 belong to the ‘of-f-ice’ explanation given elsewhere. These disc nodes are kind of special as at some point they also keep information about breakpoints and nested ligatures.

The `pre`, `post` and `replace` fields at the Lua end are in fact indirectly accessed and have a `prev` pointer that is not `nil`. This means that when you mess around with the head of these (three) lists, you also need to reassign them because that will restore the proper `prev` pointer, so:

```
pre = d.pre
-- change the list starting with pre
d.pre = pre
```

Otherwise you can end up with an invalid internal perception of reality and LuaTeX might even decide to crash on you. It also means that running forward over for instance `pre` is ok but backward you need to stop at `pre`. And you definitely must not mess with the node that `prev` points to, if only because it is not really a node but part of the disc data structure (so freeing it again might crash LuaTeX).

8.2.8 math nodes

Math nodes represent the boundaries of a math formula, normally wrapped into \$ signs.



| FIELD | TYPE | EXPLANATION |
|----------|--------|--|
| subtype | number | 0 = beginmath, 1 = endmath |
| attr | node | list of attributes |
| surround | number | width of the <code>\mathsurround</code> kern |

There is a set of extra fields that concern the associated glue: `width`, `stretch`, `stretch_order`, `shrink` and `shrink_order`. These are all numbers.

8.2.9 glue nodes

Skips are about the only type of data objects in traditional $\text{T}_{\text{E}}\text{X}$ that are not a simple value. They are inserted when $\text{T}_{\text{E}}\text{X}$ sees a space in the text flow but also by `\hskip` and `\vskip`. The structure that represents the glue components of a skip is called a `glue_spec`, and it has the following accessible fields:

| FIELD | TYPE | EXPLANATION |
|----------------------------|--------|---|
| <code>width</code> | number | the horizontal or vertical displacement |
| <code>stretch</code> | number | extra (positive) displacement or stretch amount |
| <code>stretch_order</code> | number | factor applied to stretch amount |
| <code>shrink</code> | number | extra (negative) displacement or shrink amount |
| <code>shrink_order</code> | number | factor applied to shrink amount |

The effective width of some glue subtypes depends on the stretch or shrink needed to make the encapsulating box fit its dimensions. For instance, in a paragraph lines normally have glue representing spaces and these stretch or shrink to make the content fit in the available space. The `effective_glue` function that takes a glue node and a parent (hlist or vlist) returns the effective width of that glue item. When you pass `true` as third argument the value will be rounded.

A `glue_spec` node is a special kind of node that is used for storing a set of glue values in registers. Originally they were also used to store properties of glue nodes (using a system of reference counts) but we now keep these properties in the glue nodes themselves, which gives a cleaner interface to Lua.

The indirect spec approach was in fact an optimization in the original $\text{T}_{\text{E}}\text{X}$ code. First of all it can save quite some memory because all these spaces that become glue now share the same specification (only the reference count is incremented), and zero testing is also a bit faster because only the pointer has to be checked (this is no longer true for engines that implement for instance protrusion where we really need to ensure that zero is zero when we test for bounds). Another side effect is that glue specifications are read-only, so in the end copies need to be made when they are used from Lua (each assignment to a field can result in a new copy). So in the end the advantages of sharing are not that high (and nowadays memory is less an issue, also given that a glue node is only a few memory words larger than a spec).

| FIELD | TYPE | EXPLANATION |
|---------|--------|--|
| subtype | number | 0 = userskip, 1 = lineskip, 2 = baselineskip, 3 = parskip, 4 = abovedisplayskip, 5 = belowdisplayskip, 6 = abovedisplayshortskip, 7 = belowdisplayshortskip, 8 = leftskip, 9 = rightskip, 10 = topskip, 11 |



= splittopskip, 12 = tabskip, 13 = spaceskip, 14 = xspaceskip, 15 = parfillskip, 16 = mathskip, 17 = thinmuskip, 18 = medmuskip, 19 = thickmuskip, 98 = conditionalmathskip, 99 = muglue, 100 = leaders, 101 = cleaders, 102 = xleaders, 103 = gleaders

| | | |
|--------|------|--------------------------------------|
| attr | node | list of attributes |
| leader | node | pointer to a box or rule for leaders |

In addition there are the width, stretch stretch_order, shrink, and shrink_order fields. Note that we use the key width in both horizontal and vertical glue. This suits the T_EX internals well so we decided to stick to that naming.

A regular word space also results in a spaceskip subtype (this used to be a userskip with subtype zero).

8.2.10 kern nodes

The `\kern` command creates such nodes but for instance the font and math machinery can also add them.

| FIELD | TYPE | EXPLANATION |
|---------|--------|--|
| subtype | number | 0 = fontkern, 1 = userkern, 2 = accentkern, 3 = italiccorrection |
| attr | node | list of attributes |
| kern | number | fixed horizontal or vertical advance |

8.2.11 penalty nodes

The `\penalty` command is one that generates these nodes.

| FIELD | TYPE | EXPLANATION |
|---------|--------|--|
| subtype | number | 0 = userpenalty, 1 = linebreakpenalty, 2 = linepenalty, 3 = wordpenalty, 4 = finalpenalty, 5 = noadpenalty, 6 = beforedisplaypenalty, 7 = afterdisplaypenalty, 8 = equationnumberpenalty |
| attr | node | list of attributes |
| penalty | number | the penalty value |

The subtypes are just informative and T_EX itself doesn't use them. When you run into an `linebreakpenalty` you need to keep in mind that it's a accumulation of `club`, `widow` and other relevant penalties.

8.2.12 glyph nodes

These are probably the mostly used nodes and although you can push them in the current list with for instance `\char` T_EX will normally do it for you when it considers some input to be text.

| FIELD | TYPE | EXPLANATION |
|---------|--------|-------------|
| subtype | number | bit field |



| | | |
|-------------------------------|---------|--|
| <code>attr</code> | node | list of attributes |
| <code>char</code> | number | the character index in the font |
| <code>font</code> | number | the font identifier |
| <code>lang</code> | number | the language identifier |
| <code>left</code> | number | the frozen <code>\lefthyphenm</code> value |
| <code>right</code> | number | the frozen <code>\righthyphenm</code> value |
| <code>uchyph</code> | boolean | the frozen <code>\uchyph</code> value |
| <code>components</code> | node | pointer to ligature components |
| <code>xoffset</code> | number | a virtual displacement in horizontal direction |
| <code>yoffset</code> | number | a virtual displacement in vertical direction |
| <code>width</code> | number | the (original) width of the character |
| <code>height</code> | number | the (original) height of the character |
| <code>depth</code> | number | the (original) depth of the character |
| <code>expansion_factor</code> | number | the to be applied <code>expansion_factor</code> |
| <code>data</code> | number | a general purpose field for users (we had room for it) |

The `width`, `height` and `depth` values are read-only. The `expansion_factor` is assigned in the `par` builder and used in the backend.

A warning: never assign a node list to the `components` field unless you are sure its internal link structure is correct, otherwise an error may be result. Valid bits for the `subtype` field are:

| BIT | MEANING |
|-----|-----------|
| 0 | character |
| 1 | ligature |
| 2 | ghost |
| 3 | left |
| 4 | right |

See section 5.2 for a detailed description of the `subtype` field.

The `expansion_factor` has been introduced as part of the separation between font- and backend. It is the result of extensive experiments with a more efficient implementation of expansion. Early versions of LuaTeX already replaced multiple instances of fonts in the backend by scaling but contrary to pdfTeX in LuaTeX we now also got rid of font copies in the frontend and replaced them by expansion factors that travel with glyph nodes. Apart from a cleaner approach this is also a step towards a better separation between front- and backend.

The `is_char` function checks if a node is a glyph node with a subtype still less than 256. This function can be used to determine if applying font logic to a glyph node makes sense. The value `nil` gets returned when the node is not a glyph, a character number is returned if the node is still tagged as character and `false` gets returned otherwise. When `nil` is returned, the `id` is also returned. The `is_glyph` variant doesn't check for a subtype being less than 256, so it returns either the character value or `nil` plus the `id`. These helpers are not always faster than separate calls but they sometimes permit making more readable tests. The `uses_font` helpers takes a node and font id and returns true when a glyph or disc node references that font.



8.2.13 boundary nodes

This node relates to the `\noboundary`, `\boundary`, `\protrusionboundary` and `\wordboundary` primitives.

| FIELD | TYPE | EXPLANATION |
|---------|--------|--|
| subtype | number | 0 = cancel, 1 = user, 2 = protrusion, 3 = word |
| attr | node | list of attributes |
| value | number | values 0-255 are reserved |

8.2.14 local_par nodes

This node is inserted at the start of a paragraph. You should not mess too much with this one.

| FIELD | TYPE | EXPLANATION |
|-----------------|--------|---|
| attr | node | list of attributes |
| pen_inter | number | local interline penalty (from <code>\localinterlinepenalty</code>) |
| pen_broken | number | local broken penalty (from <code>\localbrokenpenalty</code>) |
| dir | string | the direction of this par. see 8.2.15 |
| box_left | node | the <code>\localleftbox</code> |
| box_left_width | number | width of the <code>\localleftbox</code> |
| box_right | node | the <code>\localrightbox</code> |
| box_right_width | number | width of the <code>\localrightbox</code> |

A warning: never assign a node list to the `box_left` or `box_right` field unless you are sure its internal link structure is correct, otherwise an error may result.

8.2.15 dir nodes

Direction nodes mark parts of the running text that need a change of direction and the `\textdir` command generates them.

| FIELD | TYPE | EXPLANATION |
|-------|--------|---|
| attr | node | list of attributes |
| dir | string | the direction (but see below) |
| level | number | nesting level of this direction whatsit |

Direction specifiers are three-letter combinations of T, B, R, and L. These are built up out of three separate items:

- ▶ the first is the direction of the ‘top’ of paragraphs
- ▶ the second is the direction of the ‘start’ of lines
- ▶ the third is the direction of the ‘top’ of glyphs

However, only four combinations are accepted: TLT, TRT, RTT, and LTL. Inside actual `dir` nodes, the representation of `dir` is not a three-letter but a combination of numbers. When printed the



direction is indicated by a + or -, indicating whether the value is pushed or popped from the direction stack.

8.2.16 marginkern nodes

Margin kerns result from protrusion.

| FIELD | TYPE | EXPLANATION |
|---------|--------|-------------------------|
| subtype | number | 0 = left, 1 = right |
| attr | node | list of attributes |
| width | number | the advance of the kern |
| glyph | node | the glyph to be used |

8.3 Math noads

These are the so-called ‘noad’s and the nodes that are specifically associated with math processing. Most of these nodes contain subnodes so that the list of possible fields is actually quite small. First, the subnodes:

8.3.1 Math kernel subnodes

Many object fields in math mode are either simple characters in a specific family or math lists or node lists. There are four associated subnodes that represent these cases (in the following node descriptions these are indicated by the word <kernel>).

The next and prev fields for these subnodes are unused.

8.3.2 math_char and math_text_char subnodes

| FIELD | TYPE | EXPLANATION |
|-------|--------|---------------------|
| attr | node | list of attributes |
| char | number | the character index |
| fam | number | the family number |

The math_char is the simplest subnode field, it contains the character and family for a single glyph object. The math_text_char is a special case that you will not normally encounter, it arises temporarily during math list conversion (its sole function is to suppress a following italic correction).

8.3.3 sub_box and sub_mlist subnodes

| FIELD | TYPE | EXPLANATION |
|-----------|------|--------------------|
| attr | node | list of attributes |
| head/list | node | list of nodes |



These two subnode types are used for subsidiary list items. For `sub_box`, the head points to a ‘normal’ vbox or hbox. For `sub_mlist`, the head points to a math list that is yet to be converted.

A warning: never assign a node list to the head field unless you are sure its internal link structure is correct, otherwise an error is triggered.

8.3.4 delim subnodes

There is a fifth subnode type that is used exclusively for delimiter fields. As before, the next and prev fields are unused.

| FIELD | TYPE | EXPLANATION |
|-------------------------|--------|--|
| <code>attr</code> | node | list of attributes |
| <code>small_char</code> | number | character index of base character |
| <code>small_fam</code> | number | family number of base character |
| <code>large_char</code> | number | character index of next larger character |
| <code>large_fam</code> | number | family number of next larger character |

The fields `large_char` and `large_fam` can be zero, in that case the font that is set for the `small_fam` is expected to provide the large version as an extension to the `small_char`.

8.3.5 Math core nodes

First, there are the objects (the TeXbook calls them ‘atoms’) that are associated with the simple math objects: `ord`, `op`, `bin`, `rel`, `open`, `close`, `punct`, `inner`, `over`, `under`, `vcent`. These all have the same fields, and they are combined into a single node type with separate subtypes for differentiation.

Some noads have an option field. The values in this bitset are common:

| MEANING | BITS |
|-----------------|-------------|
| set | 0x08 |
| internal | 0x00 + 0x08 |
| internal | 0x01 + 0x08 |
| axis | 0x02 + 0x08 |
| no axis | 0x04 + 0x08 |
| exact | 0x10 + 0x08 |
| left | 0x11 + 0x08 |
| middle | 0x12 + 0x08 |
| right | 0x14 + 0x08 |
| no sub script | 0x21 + 0x08 |
| no super script | 0x22 + 0x08 |
| no script | 0x23 + 0x08 |



8.3.6 simple noad nodes

| FIELD | TYPE | EXPLANATION |
|---------|-------------|--|
| subtype | number | 0 = ord, 1 = opdisplaylimits, 2 = oplimits, 3 = opnolimits, 4 = bin, 5 = rel, 6 = open, 7 = close, 8 = punct, 9 = inner, 10 = under, 11 = over, 12 = vcenter |
| attr | node | list of attributes |
| nucleus | kernel node | base |
| sub | kernel node | subscript |
| sup | kernel node | superscript |
| options | number | bitset of rendering options |

8.3.7 accent nodes

| FIELD | TYPE | EXPLANATION |
|------------|-------------|--|
| subtype | number | 0 = bothflexible, 1 = fixedtop, 2 = fixedbottom, 3 = fixedboth |
| nucleus | kernel node | base |
| sub | kernel node | subscript |
| sup | kernel node | superscript |
| accent | kernel node | top accent |
| bot_accent | kernel node | bottom accent |
| fraction | number | larger step criterium (divided by 1000) |

8.3.8 style nodes

| FIELD | TYPE | EXPLANATION |
|-------|--------|--------------------|
| style | string | contains the style |

There are eight possibilities for the string value: one of display, text, script, or scriptscript. Each of these can have be prefixed by cramped.

8.3.9 choice nodes

| FIELD | TYPE | EXPLANATION |
|--------------|------|---------------------------------------|
| attr | node | list of attributes |
| display | node | list of display size alternatives |
| text | node | list of text size alternatives |
| script | node | list of scriptsize alternatives |
| scriptscript | node | list of scriptscriptsize alternatives |

Warning: never assign a node list to the display, text, script, or scriptscript field unless you are sure its internal link structure is correct, otherwise an error can occur.



8.3.10 radical nodes

| FIELD | TYPE | EXPLANATION |
|---------|----------------|--|
| subtype | number | 0 = radical, 1 = uradical, 2 = uroot, 3 = uunderdelimiter, 4 = uoverdelimiter, 5 = udelimiterunder, 6 = udelimiterover |
| attr | node | list of attributes |
| nucleus | kernel node | base |
| sub | kernel node | subscript |
| sup | kernel node | superscript |
| left | delimiter node | |
| degree | kernel node | only set by \Uroot |
| width | number | required width |
| options | number | bitset of rendering options |

Warning: never assign a node list to the nucleus, sub, sup, left, or degree field unless you are sure its internal link structure is correct, otherwise an error can be triggered.

8.3.11 fraction nodes

| FIELD | TYPE | EXPLANATION |
|---------|----------------|----------------------------------|
| attr | node | list of attributes |
| width | number | (optional) width of the fraction |
| num | kernel node | numerator |
| denom | kernel node | denominator |
| left | delimiter node | left side symbol |
| right | delimiter node | right side symbol |
| middle | delimiter node | middle symbol |
| options | number | bitset of rendering options |

Warning: never assign a node list to the num, or denom field unless you are sure its internal link structure is correct, otherwise an error can result.

8.3.12 fence nodes

| FIELD | TYPE | EXPLANATION |
|---------|----------------|--|
| subtype | number | 0 = unset, 1 = left, 2 = middle, 3 = right, 4 = no |
| attr | node | list of attributes |
| delim | delimiter node | delimiter specification |
| italic | number | italic correction |
| height | number | required height |
| depth | number | required depth |
| options | number | bitset of rendering options |
| class | number | spacing related class |

Warning: some of these fields are used by the renderer and might get adapted in the process.



8.4 Front-end whatsits

Whatsit nodes come in many subtypes that you can ask for them by running `node.whatsits:` `open` (0), `write` (1), `close` (2), `special` (3), `late_special` (4), `save_pos` (7), `late_lua` (8), `user_defined` (9), `pdf_literal` (16), `pdf_late_literal` (17), `pdf_refobj` (18), `pdf_annot` (19), `pdf_start_link` (20), `pdf_end_link` (21), `pdf_dest` (22), `pdf_action` (23), `pdf_thread` (24), `pdf_start_thread` (25), `pdf_end_thread` (26), `pdf_thread_data` (27), `pdf_link_data` (28), `pdf_colorstack` (29), `pdf_setmatrix` (30), `pdf_save` (31), `pdf_restore` (32), `pdf_link_state` (33).

Some of them are generic and independent of the output mode and others are specific to the chosen backend: `dvi` or `pdf`. Here we discuss the generic font-end nodes nodes.

8.4.1 open

| FIELD | TYPE | EXPLANATION |
|---------------------|--------|--------------------------------------|
| <code>attr</code> | node | list of attributes |
| <code>stream</code> | number | \TeX 's stream id number |
| <code>name</code> | string | file name |
| <code>ext</code> | string | file extension |
| <code>area</code> | string | file area (this may become obsolete) |

8.4.2 write

| FIELD | TYPE | EXPLANATION |
|---------------------|--------|---|
| <code>attr</code> | node | list of attributes |
| <code>stream</code> | number | \TeX 's stream id number |
| <code>data</code> | table | a table representing the token list to be written |

8.4.3 close

| FIELD | TYPE | EXPLANATION |
|---------------------|--------|----------------------------|
| <code>attr</code> | node | list of attributes |
| <code>stream</code> | number | \TeX 's stream id number |

8.4.4 user_defined

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

| FIELD | TYPE | EXPLANATION |
|----------------------|--------|--------------------|
| <code>attr</code> | node | list of attributes |
| <code>user_id</code> | number | id number |



| | | |
|-------|--------|-------------------|
| type | number | type of the value |
| value | number | a Lua number |
| | node | a node list |
| | string | a Lua string |
| | table | a Lua table |

The type can have one of six distinct values. The number is the ascii value if the first character of the type name (so you can use `string.byte("l")` instead of 108).

| VALUE | MEANING | EXPLANATION |
|-------|---------|---|
| 97 | a | list of attributes (a node list) |
| 100 | d | a Lua number |
| 108 | l | a Lua value (table, number, boolean, etc) |
| 110 | n | a node list |
| 115 | s | a Lua string |
| 116 | t | a Lua token list in Lua table form (a list of triplets) |

8.4.5 save_pos

| FIELD | TYPE | EXPLANATION |
|-------|------|--------------------|
| attr | node | list of attributes |

8.4.6 late_lua

| FIELD | TYPE | EXPLANATION |
|-------|--------------------|--|
| attr | node | list of attributes |
| data | string or function | the to be written information stored as Lua value |
| token | string | the to be written information stored as token list |
| name | string | the name to use for Lua error reporting |

The difference between `data` and `string` is that on assignment, the `data` field is converted to a token list, cf. use as `\latelua`. The `string` version is treated as a literal string.

When a function is used, it gets called with as first argument the node that triggers the call.

8.5 DVI backend whatsits

8.5.1 special

There is only one dvi backend whatsit, and it just flushes its content to the output file.

| FIELD | TYPE | EXPLANATION |
|-------|--------|---------------------------------------|
| attr | node | list of attributes |
| data | string | the <code>\special</code> information |



8.6 PDF backend whatsits

8.6.1 pdf_literal and pdf_late_literal

| FIELD | TYPE | EXPLANATION |
|-------|--------|--|
| attr | node | list of attributes |
| mode | number | the 'mode' setting of this literal |
| data | string | the to be written information stored as Lua string |
| token | string | the to be written information stored as token list |

Possible mode values are:

| VALUE | KEYWORD |
|-------|---------|
| 0 | origin |
| 1 | page |
| 2 | direct |
| 3 | raw |
| 4 | text |

The higher the number, the less checking and the more you can run into trouble. Especially the raw variant can produce bad pdf so you can best check what you generate.

8.6.2 pdf_refobj

| FIELD | TYPE | EXPLANATION |
|--------|--------|----------------------------------|
| attr | node | list of attributes |
| objnum | number | the referenced pdf object number |

8.6.3 pdf_annot

| FIELD | TYPE | EXPLANATION |
|--------|--------|---------------------------------------|
| attr | node | list of attributes |
| width | number | the width (not used in calculations) |
| height | number | the height (not used in calculations) |
| depth | number | the depth (not used in calculations) |
| objnum | number | the referenced pdf object number |
| data | string | the annotation data |

8.6.4 pdf_start_link

| FIELD | TYPE | EXPLANATION |
|-------|--------|--------------------------------------|
| attr | node | list of attributes |
| width | number | the width (not used in calculations) |



| | | |
|-----------|--------|---------------------------------------|
| height | number | the height (not used in calculations) |
| depth | number | the depth (not used in calculations) |
| objnum | number | the referenced pdf object number |
| link_attr | table | the link attribute token list |
| action | node | the action to perform |

8.6.5 pdf_end_link

| FIELD | TYPE | EXPLANATION |
|-------|------|-------------|
|-------|------|-------------|

| | | |
|------|------|--|
| attr | node | |
|------|------|--|

8.6.6 pdf_dest

| FIELD | TYPE | EXPLANATION |
|-------|------|-------------|
|-------|------|-------------|

| | | |
|-----------|--------|---|
| attr | node | list of attributes |
| width | number | the width (not used in calculations) |
| height | number | the height (not used in calculations) |
| depth | number | the depth (not used in calculations) |
| named_id | number | is the dest_id a string value? |
| dest_id | number | the destination id |
| | string | the destination name |
| dest_type | number | type of destination |
| xyz_zoom | number | the zoom factor (times 1000) |
| objnum | number | the pdf object number; for structure references the pdf object number of the linked structure element |

8.6.7 pdf_action

These are a special kind of items that only appear inside pdf start link objects.

| FIELD | TYPE | EXPLANATION |
|-------|------|-------------|
|-------|------|-------------|

| | | |
|-------------|------------------|---|
| action_type | number | the kind of action involved |
| action_id | number or string | token list reference or string |
| named_id | number | are dest_id and struct_id string values? |
| file | string | the target filename |
| new_window | number | the window state of the target |
| data | string | the name of the destination |
| struct_id | nil | the action does not reference a structure destination |
| | number | id of the referenced structure destination |
| | string | name of the referenced structure destination |

Valid action types are:

| VALUE | MEANING |
|-------|---------|
|-------|---------|

| | |
|---|------|
| 0 | page |
|---|------|



| | |
|---|--------|
| 1 | goto |
| 2 | thread |
| 3 | user |

Valid window types are:

| VALUE | MEANING |
|-------|---------|
| 0 | notset |
| 1 | new |
| 2 | nonew |

8.6.8 pdf_thread

| FIELD | TYPE | EXPLANATION |
|-------------|--------|---------------------------------------|
| attr | node | list of attributes |
| width | number | the width (not used in calculations) |
| height | number | the height (not used in calculations) |
| depth | number | the depth (not used in calculations) |
| named_id | number | is tread_id a string value? |
| tread_id | number | the thread id |
| | string | the thread name |
| thread_attr | number | extra thread information |

8.6.9 pdf_start_thread

| FIELD | TYPE | EXPLANATION |
|-------------|--------|---------------------------------------|
| attr | node | list of attributes |
| width | number | the width (not used in calculations) |
| height | number | the height (not used in calculations) |
| depth | number | the depth (not used in calculations) |
| named_id | number | is tread_id a string value? |
| tread_id | number | the thread id |
| | string | the thread name |
| thread_attr | number | extra thread information |

8.6.10 pdf_end_thread

| FIELD | TYPE | EXPLANATION |
|-------|------|-------------|
| attr | node | |

8.6.11 pdf_colorstack

| FIELD | TYPE | EXPLANATION |
|-------|------|--------------------|
| attr | node | list of attributes |



| | | |
|---------|--------|----------------------|
| stack | number | colorstack id number |
| command | number | command to execute |
| data | string | data |

8.6.12 pdf_setmatrix

| FIELD | TYPE | EXPLANATION |
|-------|--------|--------------------|
| attr | node | list of attributes |
| data | string | data |

8.6.13 pdf_save

| FIELD | TYPE | EXPLANATION |
|-------|------|--------------------|
| attr | node | list of attributes |

8.6.14 pdf_restore

| FIELD | TYPE | EXPLANATION |
|-------|------|--------------------|
| attr | node | list of attributes |

8.7 The node library

8.7.1 Introduction

The node library contains functions that facilitate dealing with (lists of) nodes and their values. They allow you to create, alter, 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.

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 freeing 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. Normally the setters and getters handle this for you.

There are statistics available with regards to the allocated node memory, which can be handy for tracing.

8.7.2 `is_node`

```
<boolean|integer> t =  
  node.is_node(<any> item)
```

This function returns a number (the internal index of the node) if the argument is a userdata object of type `<node>` and false when no node is passed.

8.7.3 `types and whatsits`

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

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

TeX’s ‘whatsits’ all have the same id. The various subtypes are defined by their subtype fields. The function is much like `types`, except that it provides an array of subtype mappings.

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

8.7.4 `id`

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

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

8.7.5 `type and subtype`

If the argument is a number, then the next function converts an internal numeric representation to an external string representation. Otherwise, it will return the string node if the object represents a node, and `nil` otherwise.



```
<string> type =  
    node.type(<any> n)
```

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

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

8.7.6 fields

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.

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

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

8.7.7 has_field

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

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

8.7.8 new

The `new` function creates a new node. All its fields are initialized to either zero or `nil` except for `id` and `subtype`. Instead of numbers you can also use strings (names). If you create a new whatsit node the second argument is required. As with all node functions, this function creates a node at the $\text{T}_{\text{E}}\text{X}$ level.

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

8.7.9 free, flush_node and flush_list

The next one removes the node `n` from $\text{T}_{\text{E}}\text{X}$'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.

```
<node> next =
```



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

The `free` function returns the next field of the freed node, while the `flush_node` alternative returns nothing.

A list starting with node `n` can be flushed from T_EX's memory too. 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.

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

8.7.10 copy and copy_list

This 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.

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

A deep copy of the node list that starts at `n` can be created too. If `m` is also given, the copy stops just before node `m`.

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

Note that you cannot copy attribute lists this way. However, there is normally no need to copy attribute lists as when you do assignments to the `attr` field or make changes to specific attributes, the needed copying and freeing takes place automatically.

8.7.11 prev and next

These returns the node preceding or following the given node, or `nil` if there is no such node.

```
<node> m =
  node.next(<node> n)
<node> m =
  node.prev(<node> n)
```

8.7.12 current_attr

This returns the currently active list of attributes, if there is one.

```
<node> m =
  node.current_attr()
```

The intended usage of `current_attr` is as follows:



```

local x1 = node.new("glyph")
x1.attr = node.current_attr()
local x2 = node.new("glyph")
x2.attr = node.current_attr()

```

or:

```

local x1 = node.new("glyph")
local x2 = node.new("glyph")
local ca = node.current_attr()
x1.attr = ca
x2.attr = ca

```

The attribute lists are ref counted and the assignment takes care of incrementing the refcount. You cannot expect the value `ca` to be valid any more when you assign attributes (using `tex.setattribute`) or when control has been passed back to `TEX`.

Note: this function is somewhat experimental, and it returns the *actual* attribute list, not a copy thereof. Therefore, changing any of the attributes in the list will change these values for all nodes that have the current attribute list assigned to them.

8.7.13 hpack

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. The second return value is the badness of the generated box.

```

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

```

Caveat: there can be unexpected side-effects to this function, like updating some of the `\marks` and `\inserts`. Also note that the content of `h` is the original node list `n`: if you call `node.free(h)` you will also free the node list itself, unless you explicitly set the `list` field to `nil` beforehand. And in a similar way, calling `node.free(n)` will invalidate `h` as well!

8.7.14 vpack

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

```

<node> h, <number> b =

```



```

node.vpack(<node> n)
<node> h, <number> b =
    node.vpack(<node> n, <number> w, <string> info)
<node> h, <number> b =
    node.vpack(<node> n, <number> w, <string> info, <string> dir)

```

The second return value is the badness of the generated box. See the description of `hpack` for a few memory allocation caveats.

8.7.15 `prepend_prevdepth`

This function is somewhat special in the sense that it is an experimental helper that adds the interlinespace to a line keeping the `baselineskip` and `lineskip` into account.

```

<node> n, <number> delta =
    node.prepend_prevdepth(<node> n, <number> prevdepth)

```

8.7.16 `dimensions` and `rangedimensions`

```

<number> w, <number> h, <number> d =
    node.dimensions(<node> n)
<number> w, <number> h, <number> d =
    node.dimensions(<node> n, <string> dir)
<number> w, <number> h, <number> d =
    node.dimensions(<node> n, <node> t)
<number> w, <number> h, <number> d =
    node.dimensions(<node> n, <node> t, <string> dir)

```

This function calculates the natural in-line dimensions of the node list starting at node `n` and terminating just before node `t` (or the end of the list, if there is no second argument). The return values are scaled points. An alternative format that starts with glue parameters as the first three arguments is also possible:

```

<number> w, <number> h, <number> d =
    node.dimensions(<number> glue_set, <number> glue_sign, <number> glue_order,
        <node> n)
<number> w, <number> h, <number> d =
    node.dimensions(<number> glue_set, <number> glue_sign, <number> glue_order,
        <node> n, <string> dir)
<number> w, <number> h, <number> d =
    node.dimensions(<number> glue_set, <number> glue_sign, <number> glue_order,
        <node> n, <node> t)
<number> w, <number> h, <number> d =
    node.dimensions(<number> glue_set, <number> glue_sign, <number> glue_order,
        <node> n, <node> t, <string> dir)

```



This calling method takes glue settings into account and is especially useful for finding the actual width of a sublist of nodes that are already boxed, for example in code like this, which prints the width of the space in between the a and b as it would be if `\box0` was used as-is:

```
\setbox0 = \hbox to 20pt {a b}

\directlua{print (node.dimensions(
    tex.box[0].glue_set,
    tex.box[0].glue_sign,
    tex.box[0].glue_order,
    tex.box[0].head.next,
    node.tail(tex.box[0].head)
)) }
```

You need to keep in mind that this is one of the few places in \TeX where floats are used, which means that you can get small differences in rounding when you compare the width reported by `hpack` with `dimensions`.

The second alternative saves a few lookups and can be more convenient in some cases:

```
<number> w, <number> h, <number> d =
    node.rangedimensions(<node> parent, <node> first)
<number> w, <number> h, <number> d =
    node.rangedimensions(<node> parent, <node> first, <node> last)
```

8.7.17 `mlist_to_hlist`

```
<node> h =
    node.mlist_to_hlist(<node> n, <string> display_type, <boolean> penalties)
```

This runs the internal `mlist` to `hlist` conversion, converting the math list in `n` into the horizontal list `h`. The interface is exactly the same as for the callback `mlist_to_hlist`.

8.7.18 `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.

8.7.19 `tail`

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

Returns the last node of the node list that starts at `n`.



8.7.20 length and type count

```
<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.

```
<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 a 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.

8.7.21 is_char and is_glyph

The subtype of a glyph node signals if the glyph is already turned into a character reference or not.

```
<boolean> b =  
    node.is_char(<node> n)  
<boolean> b =  
    node.is_glyph(<node> n)
```

8.7.22 traverse

```
<node> t, id, subtype =  
    node.traverse(<node> n)
```

This is a Lua iterator that loops over the node list that starts at *n*. Typically code looks like this:

```
for n in node.traverse(head) do  
    ...  
end
```

is functionally equivalent to:

```
do  
    local n  
    local function f (head,var)  
        local t  
        if var == nil then  
            t = head
```



```

    else
        t = var.next
    end
    return t
end
while true do
    n = f (head, n)
    if n == nil then break end
    ...
end
end
end

```

It should be clear from the definition of the function `f` that even though it is possible to add or remove nodes from the node list while traversing, you have to take great care to make sure all the next (and prev) pointers remain valid.

If the above is unclear to you, see the section ‘For Statement’ in the Lua Reference Manual.

8.7.23 `traverse_id`

```

<node> t, subtype =
    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.

See the previous section for details. The change is in the local function `f`, which now does an extra while loop checking against the upvalue `id`:

```

local function f(head,var)
    local t
    if var == nil then
        t = head
    else
        t = var.next
    end
    while not t.id == id do
        t = t.next
    end
    return t
end

```

8.7.24 `traverse_char` and `traverse_glyph`

The `traverse_char` iterator loops over the glyph nodes in a list. Only nodes with a subtype less than 256 are seen.

```

<node> n, char, font =

```




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

The `traverse_glyph` iterator loops over a list and returns the list and filters all glyphs:

```
<node> n, char, font =  
node.traverse_glyph(<node> n)
```

8.7.25 `traverse_list`

This iterator loops over the `hlist` and `vlist` nodes in a list.

```
<node> n, id, subtype, list =  
node.traverse_list(<node> n)
```

The four return values can save some time compared to fetching these fields but in practice you seldom need them all. So consider it a (side effect of experimental) convenience.

8.7.26 `has_glyph`

This function returns the first glyph or disc node in the given list:

```
<node> n =  
node.has_glyph(<node> n)
```

8.7.27 `end_of_math`

```
<node> t =  
node.end_of_math(<node> start)
```

Looks for and returns the next `math_node` following the `start`. If the given node is a math end node this helper returns that node, else it follows the list and returns the next math endnote. If no such node is found `nil` is returned.

8.7.28 `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 following the `current` in the calling argument, and is only passed back as a convenience (or `nil`, if there is no such node). The returned `head` is more important, because if the function is called with `current` equal to `head`, it will be changed.

8.7.29 `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 node `new`, set up to be part of the list (with correct next field). If `head` is initially `nil`, it will become `new`.

8.7.30 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 node `new`, set up to be part of the list (with correct next field). If `head` is initially `nil`, it will become `new`.

8.7.31 first_glyph

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

Returns the first node in the list starting at `n` that is a glyph node with a subtype indicating it is a glyph, or `nil`. If `m` is given, processing stops at (but including) that node, otherwise processing stops at the end of the list.

8.7.32 ligaturing

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

Apply T_EX-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).

8.7.33 kerning

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

Apply T_EX-style kerning to the specified node list. 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).



8.7.34 unprotect_glyph[s]

```
node.unprotect_glyph(<node> n)
node.unprotect_glyphs(<node> n, [<node> ,m])
```

Subtracts 256 from all glyph node subtypes. This and the next function are helpers to convert from characters to glyphs during node processing. The second argument is optional and indicates the end of a range.

8.7.35 protect_glyph[s]

```
node.protect_glyph(<node> n)
node.protect_glyphs(<node> n, [<node> m])
```

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 subtraction of 256. A single character can be marked by the singular call. The second argument is optional and indicates the end of a range.

8.7.36 last_node

```
<node> n =
  node.last_node()
```

This function pops the last node from T_EX's 'current list'. It returns that node, or nil if the current list is empty.

8.7.37 write

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

This function that will append a node list to T_EX's 'current list'. The node list is not deep-copied! There is no error checking either! You might need to enforce horizontal mode in order for this to work as expected.

8.7.38 protrusion_skippable

```
<boolean> skippable =
  node.protrusion_skippable(<node> n)
```

Returns true if, for the purpose of line boundary discovery when character protrusion is active, this node can be skipped.

8.8 Glue handling

8.8.1 setglue

You can set the five properties of a glue in one go. Non-numeric values are equivalent to zero and reset a property.



```
node.setglue(<node> n)
node.setglue(<node> n,width,stretch,shrink,stretch_order,shrink_order)
```

When you pass values, only arguments that are numbers are assigned so

```
node.setglue(n,655360,false,65536)
```

will only adapt the width and shrink.

When a list node is passed, you set the glue, order and sign instead.

8.8.2 getglue

The next call will return 5 values or nothing when no glue is passed.

```
<integer> width, <integer> stretch, <integer> shrink, <integer> stretch_order,
<integer> shrink_order = node.getglue(<node> n)
```

When the second argument is false, only the width is returned (this is consistent with `tex.get`).

When a list node is passed, you get back the glue that is set, the order of that glue and the sign.

8.8.3 is_zero_glue

This function returns true when the width, stretch and shrink properties are zero.

```
<boolean> isglue =
node.is_zero_glue(<node> n)
```

8.9 Attribute handling

8.9.1 Attributes

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.

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

8.9.2 attribute_list nodes

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 |
|-------------------|-------------------|--------------------------------|
| <code>next</code> | <code>node</code> | pointer to the first attribute |



8.9.3 attr nodes

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.

| FIELD | TYPE | EXPLANATION |
|---------------------|---------------------|-------------------------------|
| <code>next</code> | <code>node</code> | pointer to the next attribute |
| <code>number</code> | <code>number</code> | the attribute type id |
| <code>value</code> | <code>number</code> | the attribute value |

As mentioned it's better to use the official helpers rather than edit these fields directly. For instance the `prev` field is used for other purposes and there is no double linked list.

8.9.4 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`.

8.9.5 get_attribute

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

Tests if a node has an attribute with number `id` set. It returns the value, or, if no match is found, `nil`. If no `id` is given then the zero attributes is assumed.

8.9.6 find_attribute

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

Finds the first node that has attribute with number `id` set. It returns the value and the node if there is a match and otherwise nothing.

8.9.7 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.



8.9.8 unset_attribute

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

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`.

8.9.9 slide

This helper makes sure that the node lists is double linked and returns the found tail node.

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

After some callbacks automatic sliding takes place. This feature can be turned off with `node.fix_node_lists(false)` but you better make sure then that you don't mess up lists. In most cases \TeX itself only uses next pointers but your other callbacks might expect proper prev pointers too. Future versions of \LuaTeX can add more checking but this will not influence usage.

8.9.10 check_discretionary, check_discretionaries

When you fool around with disc nodes you need to be aware of the fact that they have a special internal data structure. As long as you reassign the fields when you have extended the lists it's ok because then the tail pointers get updated, but when you add to list without reassigning you might end up in trouble when the linebreak routine kicks in. You can call this function to check the list for issues with disc nodes.

```
node.check_discretionary(<node> n)  
node.check_discretionaries(<node> head)
```

The plural variant runs over all disc nodes in a list, the singular variant checks one node only (it also checks if the node is a disc node).

8.9.11 flatten_discretionaries

This function will remove the discretionaries in the list and inject the replace field when set.

```
<node> head, count = node.flatten_discretionaries(<node> n)
```

8.9.12 family_font

When you pass a proper family identifier the next helper will return the font currently associated with it. You can normally also access the font with the normal font field or getter because it will resolve the family automatically for noads.



```
<integer> id =  
    node.family_font(<integer> fam)
```

8.10 Two access models

Deep down in $\text{T}_{\text{E}}\text{X}$ a node has a number which is a numeric entry in a memory table. In fact, this model, where $\text{T}_{\text{E}}\text{X}$ manages memory is real fast and one of the reasons why plugging in callbacks that operate on nodes is quite fast too. Each node gets a number that is in fact an index in the memory table and that number often is reported when you print node related information. You go from userdata nodes and there numeric references and back with:

```
<integer> d = node.direct.todirect(<node> n)  
<node> n = node.direct.tonode(<integer> d)
```

The userdata model is rather robust as it is a virtual interface with some additional checking while the more direct access which uses the node numbers directly. However, even with userdata you can get into troubles when you free nodes that are no longer allocated or mess up lists. if you apply `tostring` to a node you see its internal (direct) number and id.

The first model provides key based access while the second always accesses fields via functions:

```
nodeobject.char  
getfield(nodenum, "char")
```

If you use the direct model, even if you know that you deal with numbers, you should not depend on that property but treat it as an abstraction just like traditional nodes. In fact, the fact that we use a simple basic datatype has the penalty that less checking can be done, but less checking is also the reason why it's somewhat faster. An important aspect is that one cannot mix both methods, but you can cast both models. So, multiplying a node number makes no sense.

So our advice is: use the indexed (table) approach when possible and investigate the direct one when speed might be a real issue. For that reason $\text{LuaT}_{\text{E}}\text{X}$ also provide the `get*` and `set*` functions in the top level node namespace. There is a limited set of getters. When implementing this direct approach the regular index by key variant was also optimized, so direct access only makes sense when nodes are accessed millions of times (which happens in some font processing for instance).

We're talking mostly of getters because setters are less important. Documents have not that many content related nodes and setting many thousands of properties is hardly a burden contrary to millions of consultations.

Normally you will access nodes like this:

```
local next = current.next  
if next then  
    -- do something  
end
```

Here `next` is not a real field, but a virtual one. Accessing it results in a metatable method being called. In practice it boils down to looking up the node type and based on the node type checking



for the field name. In a worst case you have a node type that sits at the end of the lookup list and a field that is last in the lookup chain. However, in successive versions of LuaTeX these lookups have been optimized and the most frequently accessed nodes and fields have a higher priority.

Because in practice the next accessor results in a function call, there is some overhead involved. The next code does the same and performs a tiny bit faster (but not that much because it is still a function call but one that knows what to look up).

```
local next = node.next(current)
if next then
  -- do something
end
```

Some accessors are used frequently and for these we provide more efficient helpers:

| FUNCTION | EXPLANATION |
|-------------------------|---|
| <code>getnext</code> | parsing nodelist always involves this one |
| <code>getprev</code> | used less but a logical companion to <code>getnext</code> |
| <code>getboth</code> | returns the next and prev pointer of a node |
| <code>getid</code> | consulted a lot |
| <code>getsubtype</code> | consulted less but also a topper |
| <code>getfont</code> | used a lot in OpenType handling (glyph nodes are consulted a lot) |
| <code>getchar</code> | idem and also in other places |
| <code>getwhd</code> | returns the width, height and depth of a list, rule or (unexpanded) glyph as well as glue (its spec is looked at) and unset nodes |
| <code>getdisc</code> | returns the pre, post and replace fields and optionally when true is passed also the tail fields |
| <code>getlist</code> | we often parse nested lists so this is a convenient one too |
| <code>getleader</code> | comparable to list, seldom used in TeX (but needs frequent consulting like lists; leaders could have been made a dedicated node type) |
| <code>getfield</code> | generic getter, sufficient for the rest (other field names are often shared so a specific getter makes no sense then) |
| <code>getbox</code> | gets the given box (a list node) |
| <code>getoffsets</code> | gets the <code>xoffset</code> and <code>yoffset</code> of a glyph or left and right values of a rule |

In the direct namespace there are more such helpers and most of them are accompanied by setters. The getters and setters are clever enough to see what node is meant. We don't deal with `whatsit` nodes: their fields are always accessed by name. It doesn't make sense to add getters for all fields, we just identifier the most likely candidates. In complex documents, many node and fields types never get seen, or seen only a few times, but for instance glyphs are candidates for such optimization. The `node.direct` interface has some more helpers.²

The `setdisc` helper takes three (optional) arguments plus an optional fourth indicating the subtype. Its `getdisc` takes an optional boolean; when its value is `true` the tail nodes will also be returned. The `setfont` helper takes an optional second argument, it being the character. The `directmode` setter `setlink` takes a list of nodes and will link them, thereby ignoring `nil` entries.

² We can define the helpers in the node namespace with `getfield` which is about as efficient, so at some point we might provide that as module.



The first valid node is returned (beware: for good reason it assumes single nodes). For rarely used fields no helpers are provided and there are a few that probably are used seldom too but were added for consistency. You can of course always define additional accessors using `getfield` and `setfield` with little overhead. When the second argument of `setattributelist` is true the current attribute list is assumed.

| FUNCTION | NODE | DIRECT |
|--------------------------------------|------|--------|
| <code>check_discretionaries</code> | + | + |
| <code>check_discretionary</code> | + | + |
| <code>copy_list</code> | + | + |
| <code>copy</code> | + | + |
| <code>count</code> | + | + |
| <code>current_attr</code> | + | + |
| <code>dimensions</code> | + | + |
| <code>effective_glue</code> | + | + |
| <code>end_of_math</code> | + | + |
| <code>family_font</code> | + | - |
| <code>fields</code> | + | - |
| <code>find_attribute</code> | + | + |
| <code>first_glyph</code> | + | + |
| <code>fix_node_lists</code> | + | - |
| <code>flatten_discretionaries</code> | + | + |
| <code>flush_list</code> | + | + |
| <code>flush_node</code> | + | + |
| <code>flush_properties_table</code> | + | + |
| <code>free</code> | + | + |
| <code>get_attribute</code> | + | + |
| <code>get_properties_table</code> | + | + |
| <code>get_synctex_fields</code> | - | + |
| <code>getattributelist</code> | - | + |
| <code>getboth</code> | + | + |
| <code>getbox</code> | - | + |
| <code>getchar</code> | + | + |
| <code>getcomponents</code> | - | + |
| <code>getdata</code> | - | + |
| <code>getdepth</code> | - | + |
| <code>getdirection</code> | - | + |
| <code>getdir</code> | - | + |
| <code>getdisc</code> | + | + |
| <code>getexpansion</code> | - | + |
| <code>getfam</code> | - | + |
| <code>getfield</code> | + | + |
| <code>getfont</code> | + | + |
| <code>getglue</code> | + | + |
| <code>getheight</code> | - | + |
| <code>getid</code> | + | + |



| | | |
|----------------------|---|---|
| getkern | - | + |
| getlang | - | + |
| getleader | + | + |
| getlist | + | + |
| getnext | + | + |
| getnucleus | - | + |
| getoffsets | - | + |
| getpenalty | - | + |
| getprev | + | + |
| getproperty | + | + |
| getshift | - | + |
| getsubtype | + | + |
| getsub | - | + |
| getsup | - | + |
| getwhd | + | + |
| getwidth | - | + |
| has_attribute | + | + |
| has_field | + | + |
| has_glyph | + | + |
| hpack | + | + |
| hyphenating | - | + |
| id | + | - |
| insert_after | + | + |
| insert_before | + | + |
| is_char | + | + |
| is_direct | - | + |
| is_glyph | + | + |
| is_node | + | + |
| is_zero_glue | + | + |
| kerning | + | + |
| last_node | + | + |
| length | + | + |
| ligaturing | + | + |
| make_extensible | + | - |
| mlist_to_hlist | + | - |
| new | + | + |
| next | + | - |
| prepend_prevdepth | + | + |
| prev | + | - |
| protect_glyphs | + | + |
| protect_glyph | + | + |
| protrusion_skippable | + | + |
| rangedimensions | + | + |
| remove | + | + |
| set_attribute | + | + |
| set_properties_mode | + | + |



| | | |
|--------------------|---|---|
| set_synctex_fields | - | + |
| setattributelist | - | + |
| setboth | - | + |
| setbox | - | + |
| setchar | - | + |
| setcomponents | - | + |
| setdata | - | + |
| setdepth | - | + |
| setdirection | - | + |
| setdir | - | + |
| setdisc | - | + |
| setexpansion | - | + |
| setfam | - | + |
| setfield | + | + |
| setfont | - | + |
| setglue | + | + |
| setheight | - | + |
| setkern | - | + |
| setlang | - | + |
| setleader | - | + |
| setlink | - | + |
| setlist | - | + |
| setnext | - | + |
| setnucleus | - | + |
| setoffsets | - | + |
| setpenalty | - | + |
| setprev | - | + |
| setproperty | + | + |
| setshift | - | + |
| setsplit | - | + |
| setsubtype | - | + |
| setsub | - | + |
| setsup | - | + |
| setwhd | - | + |
| setWidth | - | + |
| slide | + | + |
| subtypes | + | - |
| subtype | + | - |
| tail | + | + |
| todirect | - | + |
| tonode | - | + |
| tostring | + | + |
| traverse_char | + | + |
| traverse_glyph | + | + |
| traverse_id | + | + |
| traverse_list | - | + |



| | | |
|------------------|---|---|
| traverse | + | + |
| types | + | - |
| type | + | - |
| unprotect_glyphs | + | + |
| unprotect_glyph | + | + |
| unset_attribute | + | + |
| usedlist | + | + |
| uses_font | + | + |
| values | + | - |
| vpack | + | + |
| whatsits | + | - |
| write | + | + |

The `node.next` and `node.prev` functions will stay but for consistency there are variants called `getnext` and `getprev`. We had to use `get` because `node.id` and `node.subtype` are already taken for providing meta information about nodes. Note: The getters do only basic checking for valid keys. You should just stick to the keys mentioned in the sections that describe node properties.

Some of the getters and setters handle multiple node types, given that the field is relevant. In that case, some field names are considered similar (like `kern` and `width`, or `data` and `value`. In retrospect we could have normalized field names better but we decided to stick to the original (internal) names as much as possible. After all, at the Lua end one can easily create synonyms.

Some nodes have indirect references. For instance a math character refers to a family instead of a font. In that case we provide a virtual font field as accessor. So, `getfont` and `.font` can be used on them. The same is true for the `width`, `height` and `depth` of glue nodes. These actually access the `spec` node properties, and here we can set as well as get the values.

In some places LuaTeX can do a bit of extra checking for valid node lists and you can enable that with:

```
node.fix_node_lists(<boolean> b)
```

You can set and query the SyncTeX fields, a file number aka tag and a line number, for a glue, kern, hlist, vlist, rule and math nodes as well as glyph nodes (although this last one is not used in native SyncTeX).

```
node.direct.set_synctex_fields(<integer> n, <integer> f, <integer> l)
<integer> f, <integer> l =
  node.direct.get_synctex_fields(<integer> n)
```

Of course you need to know what you're doing as no checking on sane values takes place. Also, the `synctex` interpreter used in editors is rather peculiar and has some assumptions (heuristics).

8.11 Properties

Attributes are a convenient way to relate extra information to a node. You can assign them at the TeX end as well as at the Lua end and consult them at the Lua end. One big advantage is that they obey grouping. They are linked lists and normally checking for them is pretty efficient, even



if you use a lot of them. A macro package has to provide some way to manage these attributes at the \TeX end because otherwise clashes in their usage can occur.

Each node also can have a properties table and you can assign values to this table using the `setproperty` function and get properties using the `getproperty` function. Managing properties is way more demanding than managing attributes.

Take the following example:

```
\directlua {
  local n = node.new("glyph")

  node.setproperty(n,"foo")
  print(node.getproperty(n))

  node.setproperty(n,"bar")
  print(node.getproperty(n))

  node.free(n)
}
```

This will print `foo` and `bar` which in itself is not that useful when multiple mechanisms want to use this feature. A variant is:

```
\directlua {
  local n = node.new("glyph")

  node.setproperty(n,{ one = "foo", two = "bar" })
  print(node.getproperty(n).one)
  print(node.getproperty(n).two)

  node.free(n)
}
```

This time we store two properties with the node. It really makes sense to have a table as property because that way we can store more. But in order for that to work well you need to do it this way:

```
\directlua {
  local n = node.new("glyph")

  local t = node.getproperty(n)

  if not t then
    t = { }
    node.setproperty(n,t)
  end
  t.one = "foo"
  t.two = "bar"
```



```

    print(node.getproperty(n).one)
    print(node.getproperty(n).two)

    node.free(n)
}

```

Here our own properties will not overwrite other users properties unless of course they use the same keys. So, eventually you will end up with something:

```

\directlua {
    local n = node.new("glyph")

    local t = node.getproperty(n)

    if not t then
        t = { }
        node.setproperty(n,t)
    end
    t.myself = { one = "foo", two = "bar" }

    print(node.getproperty(n).myself.one)
    print(node.getproperty(n).myself.two)

    node.free(n)
}

```

This assumes that only you use `myself` as subtable. The possibilities are endless but care is needed. For instance, the generic font handler that ships with `ConTeXt` uses the injections subtable and you should not mess with that one!

There are a few helper functions that you normally should not touch as user: `flush_properties_table` will wipe the table (normally a bad idea), `get_properties_table` will give the table that stores properties (using direct entries) and you can best not mess too much with that one either because `LuaTeX` itself will make sure that entries related to nodes will get wiped when nodes get freed, so that the Lua garbage collector can do its job. In fact, the main reason why we have this mechanism is that it saves the user (or macro package) some work. One can easily write a property mechanism in Lua where after a shipout properties gets cleaned up but it's not entirely trivial to make sure that with each freed node also its properties get freed, due to the fact that there can be nodes left over for a next page. And having a callback bound to the node deallocator would add way to much overhead.

Managing properties in the node (de)allocator functions is disabled by default and is enabled by:

```
node.set_properties_mode(true)
```

When we copy a node list that has a table as property, there are several possibilities: we do the same as a new node, we copy the entry to the table in properties (a reference), we do a deep copy of a table in the properties, we create a new table and give it the original one as a metatable.



After some experiments (that also included timing) with these scenarios we decided that a deep copy made no sense, nor did nilling. In the end both the shallow copy and the metatable variant were both ok, although the second one is slower. The most important aspect to keep in mind is that references to other nodes in properties no longer can be valid for that copy. We could use two tables (one unique and one shared) or metatables but that only complicates matters.

When defining a new node, we could already allocate a table but it is rather easy to do that at the lua end e.g. using a metatable `__index` method. That way it is under macro package control. When deleting a node, we could keep the slot (e.g. setting it to false) but it could make memory consumption raise unneeded when we have temporary large node lists and after that only small lists. Both are not done.

So in the end this is what happens now: when a node is copied, and it has a table as property, the new node will share that table. If the second argument of `set_properties_mode` is true then a metatable approach is chosen: the copy gets its own table with the original table as metatable. If you use the generic font loader the mode is enabled that way.

A few more xperiments were done. For instance: copy attributes to the properties so that we have fast access at the Lua end. In the end the overhead is not compensated by speed and convenience, in fact, attributes are not that slow when it comes to accessing them. So this was rejected.

Another experiment concerned a bitset in the node but again the gain compared to attributes was neglectable and given the small amount of available bits it also demands a pretty strong agreement over what bit represents what, and this is unlikely to succeed in the T_EX community. It doesn't pay off.

Just in case one wonders why properties make sense: it is not so much speed that we gain, but more convenience: storing all kind of (temporary) data in attributes is no fun and this mechanism makes sure that properties are cleaned up when a node is freed. Also, the advantage of a more or less global properties table is that we stay at the Lua end. An alternative is to store a reference in the node itself but that is complicated by the fact that the register has some limitations (no numeric keys) and we also don't want to mess with it too much.





172 Nodes

9 LUA callbacks

9.1 Registering callbacks

This library has functions that register, find and list callbacks. Callbacks are Lua functions that are called in well defined places. There are two kind of callbacks: those that mix with existing functionality, and those that (when enabled) replace functionality. In mostly cases the second category is expected to behave similar to the built in functionality because in a next step specific data is expected. For instance, you can replace the hyphenation routine. The function gets a list that can be hyphenated (or not). The final list should be valid and is (normally) used for constructing a paragraph. Another function can replace the ligature builder and/or kernner. Doing something else is possible but in the end might not give the user the expected outcome. The first thing you need to do is registering a callback:

```
id, error =
    callback.register(<string> callback_name, <function> func)
id, error =
    callback.register(<string> callback_name, nil)
id, error =
    callback.register(<string> callback_name, false)
```

Here 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.

For some minor speed gain, you can assign the boolean `false` to the non-file related callbacks, doing so will prevent LuaTeX from executing whatever it would execute by default (when no callback function is registered at all). Be warned: this may cause all sorts of grief unless you know *exactly* what you are doing!

```
<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, `find` returns `nil`.

9.2 File discovery callbacks

The behaviour documented in this subsection is considered stable in the sense that there will not be backward-incompatible changes any more.



9.2.1 find_read_file and find_write_file

Your 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 Lua \TeX 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.

9.2.2 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.

9.2.3 find_output_file

Your 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.

9.2.4 find_format_file

Your 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).

9.2.5 `find_vf_file`

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

9.2.6 `find_map_file`

Like `find_font_file`, but for map files.

9.2.7 `find_enc_file`

Like `find_font_file`, but for enc files.

9.2.8 `find_pk_file`

Like `find_font_file`, but for `pk` bitmap files. This callback takes two arguments: `name` and `dpi`. In your callback you can decide to look for:

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

but other strategies are possible. It is up to you to find a 'reasonable' bitmap file to go with that specification.

9.2.9 `find_data_file`

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

9.2.10 `find_opentype_file`

Like `find_font_file`, but for OpenType font files.

9.2.11 `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 Lua_T_E_X 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.

9.2.12 `find_image_file`

Your 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 hard disk, so make sure you return something that is considered the name of a valid file by your operating system.

9.3 File reading callbacks

The behavior documented in this subsection is considered stable in the sense that there will not be backward-incompatible changes any more.

9.3.1 `open_read_file`

Your 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 function 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.

9.3.1.1 `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.

9.3.1.2 close

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

```
function(<table> env)
end
```

Your function should not return any value.

9.3.2 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 occurred (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:

| FUNCTION | USAGE |
|---------------------------------|--|
| <code>read_font_file</code> | ofm or tfm files |
| <code>read_vf_file</code> | virtual fonts |
| <code>read_map_file</code> | map files |
| <code>read_enc_file</code> | encoding files |
| <code>read_pk_file</code> | pk bitmap files |
| <code>read_data_file</code> | embedded files (as is possible with pdf objects) |
| <code>read_truetype_file</code> | TrueType font files |
| <code>read_type1_file</code> | Type1 font files |
| <code>read_opentype_file</code> | OpenType font files |



9.4 Data processing callbacks

9.4.1 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. This callback does not replace any internal code.

9.4.2 process_output_buffer

This callback allows you to change the contents of the line output buffer just before LuaTeX actually starts writing it to a file as the result of a `\write` command. It is only called for output to an actual file (that is, excluding the log, the terminal, and so called `\write 18` calls).

```
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. This callback does not replace any internal code.

9.4.3 process_jobname

This callback allows you to change the jobname given by `\jobname` in TeX and `tex.jobname` in Lua. It does not affect the internal job name or the name of the output or log files.

```
function(<string> jobname)
    return <string> adjusted_jobname
end
```

The only argument is the actual job name; you should not use `tex.jobname` inside this function or infinite recursion may occur. If you return `nil`, LuaTeX will pretend your callback never happened. This callback does not replace any internal code.

9.5 Node list processing callbacks

The description of nodes and node lists is in chapter 8.

9.5.1 contribute_filter

This callback is called when LuaTeX adds contents to list:



```
function(<string> extrainfo)
end
```

The string reports the group code. From this you can deduce from what list you can give a treat.

| VALUE | EXPLANATION |
|------------|--|
| pre_box | interline material is being added |
| pre_adjust | \vadjust material is being added |
| box | a typeset box is being added (always called) |
| adjust | \vadjust material is being added |

9.5.2 buildpage_filter

This callback is called whenever Lua_T_EX 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(<string> extrainfo)
end
```

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

| VALUE | EXPLANATION |
|----------------|--|
| alignment | a (partial) alignment is being added |
| after_output | an output routine has just finished |
| new_graf | 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 |
| end | Lua _T _E X is terminating (it's all over) |

9.5.3 build_page_insert

This callback is called when the pagebuilder adds an insert. There is not much control over this mechanism but this callback permits some last minute manipulations of the spacing before an insert, something that might be handy when for instance multiple inserts (types) are appended in a row.

```
function(<number> n, <number> i)
    return <number> register
end
```

with



| VALUE | EXPLANATION |
|-------|-------------------------|
| n | the insert class |
| i | the order of the insert |

The return value is a number indicating the skip register to use for the prepended spacing. This permits for instance a different top space (when `i` equals one) and intermediate space (when `i` is larger than one). Of course you can mess with the insert box but you need to make sure that LuaTeX is happy afterwards.

9.5.4 `pre_linebreak_filter`

This callback is called just before LuaTeX starts converting a list of nodes into a stack of `\hboxes`, after the addition of `\parfillskip`.

```
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 |
|---------------|---|
| <empty> | main vertical list |
| hbox | <code>\hbox</code> in horizontal mode |
| adjusted_hbox | <code>\hbox</code> in vertical mode |
| vbox | <code>\vbox</code> |
| vtop | <code>\vtop</code> |
| align | <code>\halign</code> or <code>\valign</code> |
| disc | discretionaries |
| insert | packaging an insert |
| vcenter | <code>\vcenter</code> |
| local_box | <code>\localleftbox</code> or <code>\localrightbox</code> |
| split_off | top of a <code>\vsplit</code> |
| split_keep | remainder of a <code>\vsplit</code> |
| align_set | alignment cell |
| fin_row | alignment row |

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

- ▶ boolean `true` signals successful processing
- ▶ `<node>` signals that the 'head' node should be replaced by the returned node
- ▶ boolean `false` signals that the 'head' node list should be ignored and flushed from memory

This callback does not replace any internal code.



9.5.5 `linebreak_filter`

This callback replaces LuaTeX's line breaking algorithm.

```
function(<node> head, <boolean> is_display)
    return <node> newhead
end
```

The returned node is the head of the list that will be added to the main vertical list, the boolean argument is true if this paragraph is interrupted by a following math display.

If you return something that is not a <node>, LuaTeX will apply the internal linebreak algorithm on the list that starts at <head>. Otherwise, the <node> you return is supposed to be the head of a list of nodes that are all allowed in vertical mode, and at least one of those has to represent a hbox. Failure to do so will result in a fatal error.

Setting this callback to false is possible, but dangerous, because it is possible you will end up in an unfixable 'deadcycles loop'.

9.5.6 `append_to_vlist_filter`

This callback is called whenever LuaTeX adds a box to a vertical list:

```
function(<node> box, <string> locationcode, <number prevdepth>,
    <boolean> mirrored)
    return list, prevdepth
end
```

It is ok to return nothing in which case you also need to flush the box or deal with it yourself. The prevdepth is also optional. Locations are box, alignment, equation, equation_number and post_linebreak. You can pass nil instead of a node.

9.5.7 `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
```

This callback does not replace any internal code.

9.5.8 `hpack_filter`

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

```
function(<node> head, <string> groupcode, <number> size,
    <string> packtype [, <string> direction] [, <node> attributelist])
```



```

    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.

The `direction` is either one of the three-letter direction specifier strings, or `nil`.

This callback does not replace any internal code.

9.5.9 `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 [, <string> direction] [, <node> attributelist]))
    return true | false | <node> newhead
end

```

This callback does not replace any internal code.

9.5.10 `hpack_quality`

This callback can be used to intercept the overflow messages that can result from packing a horizontal list (as happens in the `par` builder). The function takes a few arguments:

```

function(<string> incident, <number> detail, <node> head, <number> first,
        <number> last)
    return <node> whatever
end

```

The `incident` is one of `overflow`, `underfull`, `loose` or `tight`. The `detail` is either the amount of overflow in case of `overflow`, or the badness otherwise. The `head` is the list that is constructed (when protrusion or expansion is enabled, this is an intermediate list). Optionally you can return a node, for instance an overflow rule indicator. That node will be appended to the list (just like \TeX 's own rule would).

9.5.11 `vpack_quality`

This callback can be used to intercept the overflow messages that can result from packing a vertical list (as happens in the `page` builder). The function takes a few arguments:

```

function(<string> incident, <number> detail, <node> head, <number> first,
        <number> last)

```



end

The incident is one of `overflow`, `underfull`, `loose` or `tight`. The detail is either the amount of overflow in case of `overflow`, or the badness otherwise. The head is the list that is constructed.

9.5.12 `process_rule`

This is an experimental callback. It can be used with rules of subtype 4 (user). The callback gets three arguments: the node, the width and the height. The callback can use `pdf.print` to write code to the pdf file but beware of not messing up the final result. No checking is done.

9.5.13 `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 [, <string> direction])
    return true | false | <node> newhead
end
```

This callback does not replace any internal code.

9.5.14 `hyphenate`

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

No return values. This callback has to insert discretionary nodes in the node list it receives. Setting this callback to `false` will prevent the internal discretionary insertion pass.

9.5.15 `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 to 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.

Setting this callback to `false` will prevent the internal ligature creation pass.



You must not ruin the node list. For instance, the head normally is a local par node, and the tail a glue. Messing too much can push LuaTeX into panic mode.

9.5.16 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.

Setting this callback to `false` will prevent the internal kern insertion pass.

You must not ruin the node list. For instance, the head normally is a local par node, and the tail a glue. Messing too much can push LuaTeX into panic mode.

9.5.17 insert_local_par

Each paragraph starts with a local par node that keeps track of for instance the direction. You can hook a callback into the creator:

```
function(<node> local_par, <string> location)
end
```

There is no return value and you should make sure that the node stays valid as otherwise TeX can get confused.

9.5.18 mlist_to_hlist

This callback replaces LuaTeX's math list to node list conversion algorithm.

```
function(<node> head, <string> display_type, <boolean> need_penalties)
    return <node> newhead
end
```

The returned node is the head of the list that will be added to the vertical or horizontal list, the string argument is either `'text'` or `'display'` depending on the current math mode, the boolean argument is `true` if penalties have to be inserted in this list, `false` otherwise.

Setting this callback to `false` is bad, it will almost certainly result in an endless loop.

9.6 Information reporting callbacks

9.6.1 pre_dump

```
function()
end
```



This function is called just before dumping to a format file starts. It does not replace any code and there are neither arguments nor return values.

9.6.2 start_run

```
function()  
end
```

This callback replaces the code that prints Lua_{TEX}'s banner. Note that for successful use, this callback has to be set in the Lua initialization script, otherwise it will be seen only after the run has already started.

9.6.3 stop_run

```
function()  
end
```

This callback replaces the code that prints Lua_{TEX}'s statistics and 'output written to' messages. The engine can still do housekeeping and therefore you should not rely on this hook for postprocessing the pdf or log file.

9.6.4 start_page_number

```
function()  
end
```

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.

9.6.5 stop_page_number

```
function()  
end
```

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

9.6.6 show_error_hook

```
function()  
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. This callback does not replace any internal code.



9.6.7 show_error_message

```
function()  
end
```

This callback replaces the code that prints the error message. The usual interaction after the message is not affected.

9.6.8 show_ignored_error_message

```
function()  
end
```

This callback replaces the code that prints the error message when `\ignoreprimitiveerror` is enabled. As before, the usual interaction after the message is not affected.

9.6.9 show_lua_error_hook

```
function()  
end
```

This callback replaces the code that prints the extra Lua error message.

9.6.10 start_file

```
function(category, filename)  
end
```

This callback replaces the code that prints LuaTeX's when a file is opened like (filename for regular files. The category is a number:

| VALUE | MEANING |
|-------|---|
| 1 | a normal data file, like a TeX source |
| 2 | a font map coupling font names to resources |
| 3 | an image file (png, pdf, etc) |
| 4 | an embedded font subset |
| 5 | a fully embedded font |

9.6.11 stop_file

```
function(category)  
end
```

This callback replaces the code that prints LuaTeX's when a file is closed like the) for regular files.



9.6.12 call_edit

```
function(filename,linenumber)
end
```

This callback replaces the call to an external editor when ‘E’ is pressed in reply to an error message. Processing will end immediately after the callback returns control to the main program.

9.6.13 finish_synctex

This callback can be used to wrap up alternative synctex methods. It kicks in after the normal synctex finalizer (that happens to remove the synctex files after a run when native synctex is not enabled).

9.6.14 wrapup_run

This callback is called after the pdf and log files are closed. Use it at your own risk.

9.7 PDF related callbacks

9.7.1 finish_pdffile

```
function()
end
```

This callback is called when all document pages are already written to the pdf file and Lua-TeX is about to finalize the output document structure. Its intended use is final update of pdf dictionaries such as /Catalog or /Info. The callback does not replace any code. There are neither arguments nor return values.

9.7.2 finish_pdfpage

```
function(shippingout)
end
```

This callback is called after the pdf page stream has been assembled and before the page object gets finalized.

9.7.3 page_order_index

This is one that experts can use to juggle the page tree, a data structure that determines the order in a pdf file:

```
function(pagenum)
  return pagenum
end
```



```
end
```

Say that we have 12 pages, then we can do this:

```
callback.register("page_order_index",function(page)
    if page == 1 then return 12
    elseif page == 2 then return 11
    elseif page == 11 then return 2
    elseif page == 12 then return 1
    else return page
end)
end)
```

This will swap the first two and last two pages. You need to know the number of pages which is a side effect of the implementation. When you mess things up ... don't complain.

9.7.4 process_pdf_image_content

When a page from a pdf file is embedded its page stream as well as related objects are copied to the target file. However, it can be that the page stream has operators that assume additional resources, for instance marked text. You can decide to filter that for which LuaTeX provides a callback. Here is a simple demonstration of use:

```
pdf.setrecompress(1)

callback.register("process_pdf_image_content",function(s)
    print(s)
    return s
end)
```

You need to explicitly enable recompression because otherwise the content stream gets just passed on in its original compressed form.

9.8 Font-related callbacks

9.8.1 define_font

```
function(<string> name, <number> size, <number> id)
    return <table> font | <number> id
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 `id` is the internal number assigned to 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. In alternative, `retval` can be a previously defined fontid. This is useful if a previous definition can be reused instead of creating a whole new font structure.

Setting this callback to `false` is pointless as it will prevent font loading completely but will nevertheless generate errors.

9.8.2 `glyph_not_found` and `glyph_info`

The `glyph_not_found` callback, when set, kicks in when the backend cannot insert a glyph. When no callback is defined a message is written to the log.

```
function(<number> id, <number> char)
    -- do something with font id and char code
end
```

The `glyph_info` callback can be set to report a useful representation of a glyph.

```
function(<node> g)
    -- return a string or nil
end
```

When `nil` is returned the character code is printed, otherwise the returned string is used. By default the utf representation is shown which is not always that useful, especially when there is no real representation. Keep in mind that setting this callback can change the log in an incompatible way.

9.8.3 `provide_charproc_data`

The `provide_charproc_data` callback is triggered when the backend is writing out a userB Adefined Type 3 font:

```
function(<number> mode, <number> id, <number> char)
    if mode == 1 then
        -- preroll
        return
    elseif mode == 2 then
        -- write out the glyph contents
        return <number> stream, <number> width
    elseif mode == 3 then
        -- the overall font scale
        return <number> scale
    end
end
```

To make a user-defined Type 3 font, you need to set `encodingbytes = 0` and `psname = "none"` at the top-level when defining the font. From the `glyph_not_found` callback, you should return



the overall font scale (conventionally 0.001) in mode 3, and the index of a pdf stream (where the first operator is either `d0` or `d1`) and the width of the glyph (in sp's) in mode 2. You can generally ignore mode 1.



10 The T_EX related libraries

10.1 The lua library

10.1.1 Version information

This library contains one read-only item:

```
<string> s = lua.version
```

This returns the Lua version identifier string. The value is currently Lua 5.3.

10.1.2 Bytecode registers

Lua registers can be used to store Lua code chunks. The accepted values for assignments are functions and nil. Likewise, the retrieved value is either a function or nil.

```
lua.bytecode[<number> n] = <function> f  
lua.bytecode[<number> 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. The function must not contain any upvalues. 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]()
```

Note that the path of the file is stored in the Lua bytecode to be used in stack backtraces and therefore dumped into the format file if the above code is used in iniT_EX. If it contains private information, i.e. the user name, this information is then contained in the format file as well. This should be kept in mind when preloading files into a bytecode register in iniT_EX.

10.1.3 Chunk name registers

There is an array of 65536 (0-65535) potential chunk names for use with the \directlua and \latelua primitives.



```
lua.name[<number> n] = <string> s
<string> s = lua.name[<number> n]
```

If you want to unset a Lua name, you can assign `nil` to it. The function accessors are:

```
lua.setluaname(<number> n, <string> s)
<string> s = lua.getluaname(<number> n)
```

10.1.4 Introspection

The `getstacktop` and `andgetcalllevel` functions return numbers indicating how much nesting is going on. They are only of use as breakpoints when checking some mechanism going haywire.

10.2 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 |
|---------------------------------|--|
| <code>banner</code> | terminal display banner |
| <code>best_page_break</code> | the current best break (a node) |
| <code>buf_size</code> | current allocated size of the line buffer |
| <code>callbacks</code> | total number of executed callbacks so far |
| <code>cs_count</code> | number of control sequences |
| <code>dest_names_size</code> | pdf destination table size |
| <code>dvi_gone</code> | written dvi bytes |
| <code>dvi_ptr</code> | not yet written dvi bytes |
| <code>dyn_used</code> | token (multi-word) memory in use |
| <code>filename</code> | name of the current input file |
| <code>fix_mem_end</code> | maximum number of used tokens |
| <code>fix_mem_min</code> | minimum number of allocated words for tokens |
| <code>fix_mem_max</code> | maximum number of allocated words for tokens |
| <code>font_ptr</code> | number of active fonts |
| <code>hash_extra</code> | extra allowed hash |
| <code>hash_size</code> | size of hash |
| <code>indirect_callbacks</code> | number of those that were themselves a result of other callbacks (e.g. file readers) |
| <code>ini_version</code> | true if this is an ini \TeX run |
| <code>init_pool_ptr</code> | ini \TeX string pool index |



| | |
|---------------------------------|--|
| <code>init_str_ptr</code> | number of iniT _E X strings |
| <code>input_ptr</code> | the level of input we're at |
| <code>inputid</code> | numeric id of the current input |
| <code>largest_used_mark</code> | max referenced marks class |
| <code>lasterrorcontext</code> | last error context string (with newlines) |
| <code>lasterrorstring</code> | last T _E X error string |
| <code>lastluaerrorstring</code> | last Lua error string |
| <code>lastwarningstring</code> | last warning tag, normally an indication of in what part |
| <code>lastwarningtag</code> | last warning string |
| <code>linenumber</code> | location in the current input file |
| <code>log_name</code> | name of the log file |
| <code>luabytecode_bytes</code> | number of bytes in Lua bytecode registers |
| <code>luabytecodes</code> | number of active Lua bytecode registers |
| <code>luastate_bytes</code> | number of bytes in use by Lua interpreters |
| <code>luatex_engine</code> | the LuaT _E X engine identifier |
| <code>luatex_hashchars</code> | length to which Lua hashes strings (2 ⁿ) |
| <code>luatex_hashtype</code> | the hash method used (in LuajitT _E X) |
| <code>luatex_version</code> | the LuaT _E X version number |
| <code>luatex_revision</code> | the LuaT _E X revision string |
| <code>max_buf_stack</code> | max used buffer position |
| <code>max_in_stack</code> | max used input stack entries |
| <code>max_nest_stack</code> | max used nesting stack entries |
| <code>max_param_stack</code> | max used parameter stack entries |
| <code>max_save_stack</code> | max used save stack entries |
| <code>max_strings</code> | maximum allowed strings |
| <code>nest_size</code> | nesting stack size |
| <code>node_mem_usage</code> | a string giving insight into currently used nodes |
| <code>obj_ptr</code> | max pdf object pointer |
| <code>obj_tab_size</code> | pdf object table size |
| <code>output_active</code> | true if the <code>\output</code> routine is active |
| <code>output_file_name</code> | name of the pdf or dvi file |
| <code>param_size</code> | parameter stack size |
| <code>pdf_dest_names_ptr</code> | max pdf destination pointer |
| <code>pdf_gone</code> | written pdf bytes |
| <code>pdf_mem_ptr</code> | max pdf memory used |
| <code>pdf_mem_size</code> | pdf memory size |
| <code>pdf_os_cntr</code> | max pdf object stream pointer |
| <code>pdf_os_objidx</code> | pdf object stream index |
| <code>pdf_ptr</code> | not yet written pdf bytes |
| <code>pool_ptr</code> | string pool index |
| <code>pool_size</code> | current size allocated for string characters |
| <code>save_size</code> | save stack size |
| <code>shell_escape</code> | 0 means disabled, 1 means anything is permitted, and 2 is restricted |
| <code>safer_option</code> | 1 means safer is enforced |
| <code>luadebug_option</code> | true if the debug library is enabled at command line |
| <code>output_directory</code> | the value of the output directory |



| | |
|--------------------------|--|
| <code>kpse_used</code> | 1 means that kpse is used |
| <code>stack_size</code> | input stack size |
| <code>str_ptr</code> | number of strings |
| <code>total_pages</code> | number of written pages |
| <code>var_mem_max</code> | number of allocated words for nodes |
| <code>var_used</code> | variable (one-word) memory in use |
| <code>lc_collate</code> | the value of LC_COLLATE at startup time (becomes C at startup) |
| <code>lc_ctype</code> | the value of LC_CTYPE at startup time (becomes C at startup) |
| <code>lc_numeric</code> | the value of LC_NUMERIC at startup time |

The error and warning messages can be wiped with the `resetmessages` function. A return value can be set with `setexitcode`.

10.3 The tex library

10.3.1 Introduction

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 you can use after `\the`, is a single tokens or is sort of special in \TeX . This excludes parameters that need extra arguments, like `\the\scriptfont`. The subset comprising simple integer and dimension registers are writable as well as readable (like `\tracingcommands` and `\parindent`).

10.3.2 Internal parameter values, set and get

For all the parameters in this section, it is possible to access them directly using their names as index in the `tex` table, or by using one of the functions `tex.get` and `tex.set`.

The exact parameters and return values differ depending on the actual parameter, and so does whether `tex.set` has any effect. For the parameters that *can* be set, it is possible to use `global` as the first argument to `tex.set`; this makes the assignment global instead of local.

```
tex.set (["global",] <string> n, ...)
... = tex.get (<string> n)
```

Glue is kind of special because there are five values involved. The return value is a `glue_spec` node but when you pass `false` as last argument to `tex.get` you get the width of the glue and when you pass `true` you get all five values. Otherwise you get a node which is a copy of the internal value so you are responsible for its freeing at the Lua end. When you set a glue quantity you can either pass a `glue_spec` or upto five numbers. If you pass `true` to `get` you get 5 values returned for a glue and when you pass `false` you only get the width returned.



10.3.2.1 Integer parameters

The integer parameters accept and return Lua numbers. These are read-write:

| | |
|--|--------------------------------------|
| <code>tex.adjdemerits</code> | <code>tex.newlinechar</code> |
| <code>tex.binoppenalty</code> | <code>tex.outputpenalty</code> |
| <code>tex.brokenpenalty</code> | <code>tex.pausing</code> |
| <code>tex.catcodetable</code> | <code>tex.postdisplaypenalty</code> |
| <code>tex.clubpenalty</code> | <code>tex.predisplaydirection</code> |
| <code>tex.day</code> | <code>tex.predisplaypenalty</code> |
| <code>tex.defaultthyphenchar</code> | <code>tex.pretolerance</code> |
| <code>tex.defaultskewchar</code> | <code>tex.relpenalty</code> |
| <code>tex.delimiterfactor</code> | <code>tex.righthyphenmin</code> |
| <code>tex.displaywidowpenalty</code> | <code>tex.savinghyphcodes</code> |
| <code>tex.doublehyphdemerits</code> | <code>tex.savingvdiscards</code> |
| <code>tex.endlinechar</code> | <code>tex.showboxbreadth</code> |
| <code>tex.errorcontextlines</code> | <code>tex.showboxdepth</code> |
| <code>tex.escapechar</code> | <code>tex.time</code> |
| <code>tex.exhyphenpenalty</code> | <code>tex.tolerance</code> |
| <code>tex.fam</code> | <code>tex.tracingassigns</code> |
| <code>tex.finalhyphdemerits</code> | <code>tex.tracingcommands</code> |
| <code>tex.floatingpenalty</code> | <code>tex.tracinggroups</code> |
| <code>tex.globaldefs</code> | <code>tex.tracingifs</code> |
| <code>tex.hangafter</code> | <code>tex.tracinglostchars</code> |
| <code>tex.hbadness</code> | <code>tex.tracingmacros</code> |
| <code>tex.holdinginserts</code> | <code>tex.tracingnesting</code> |
| <code>tex.hyphenpenalty</code> | <code>tex.tracingonline</code> |
| <code>tex.interlinepenalty</code> | <code>tex.tracingoutput</code> |
| <code>tex.language</code> | <code>tex.tracingpages</code> |
| <code>tex.lastlinefit</code> | <code>tex.tracingparagraphs</code> |
| <code>tex.lefthyphenmin</code> | <code>tex.tracingrestores</code> |
| <code>tex.linepenalty</code> | <code>tex.tracingscantokens</code> |
| <code>tex.localbrokenpenalty</code> | <code>tex.tracingstats</code> |
| <code>tex.localinterlinepenalty</code> | <code>tex.uchyph</code> |
| <code>tex.looseness</code> | <code>tex.vbadness</code> |
| <code>tex.mag</code> | <code>tex.widowpenalty</code> |
| <code>tex.maxdeadcycles</code> | <code>tex.year</code> |
| <code>tex.month</code> | |

These are read-only:

| | | |
|----------------------------------|-------------------------------------|--|
| <code>tex.deadcycles</code> | <code>tex.interlinepenalties</code> | <code>tex.displaywidowpenalties</code> |
| <code>tex.insertpenalties</code> | <code>tex.clubpenalties</code> | <code>tex.prevgraf</code> |
| <code>tex.parshape</code> | <code>tex.widowpenalties</code> | <code>tex.spacefactor</code> |



10.3.2.2 Dimension parameters

The dimension parameters accept Lua numbers (signifying scaled points) or strings (with included dimension). The result is always a number in scaled points. These are read-write:

| | | |
|-------------------------------------|-------------------------------------|---------------------------------|
| <code>tex.boxmaxdepth</code> | <code>tex.mathsurround</code> | <code>tex.parindent</code> |
| <code>tex.delimitershortfall</code> | <code>tex.maxdepth</code> | <code>tex.predisplaysize</code> |
| <code>tex.displayindent</code> | <code>tex.nulldelimiterspace</code> | <code>tex.scriptslope</code> |
| <code>tex.displaywidth</code> | <code>tex.overfullrule</code> | <code>tex.splitmaxdepth</code> |
| <code>tex.emergencystretch</code> | <code>tex.pagebottomoffset</code> | <code>tex.vfuzz</code> |
| <code>tex.hangindent</code> | <code>tex.pageheight</code> | <code>tex.voffset</code> |
| <code>tex.hfuzz</code> | <code>tex.pageleftoffset</code> | <code>tex.vsize</code> |
| <code>tex.hoffset</code> | <code>tex.pagerightoffset</code> | <code>tex.prevdepth</code> |
| <code>tex.hsize</code> | <code>tex.pagetopoffset</code> | <code>tex.prevgraf</code> |
| <code>tex.lineskiplimit</code> | <code>tex.pagewidth</code> | <code>tex.spacefactor</code> |

These are read-only:

| | | |
|-----------------------------------|---------------------------------|------------------------------|
| <code>tex.pagedepth</code> | <code>tex.pagefilstretch</code> | <code>tex.pagestretch</code> |
| <code>tex.pagefilllstretch</code> | <code>tex.pagegoal</code> | <code>tex.pagetotal</code> |
| <code>tex.pagefillstretch</code> | <code>tex.pageshrink</code> | |

Beware: as with all Lua tables you can add values to them. So, the following is valid:

```
tex.foo = 123
```

When you access a \TeX parameter a look up takes place. For read-only variables that means that you will get something back, but when you set them you create a new entry in the table thereby making the original invisible.

There are a few special cases that we make an exception for: `prevdepth`, `prevgraf` and `spacefactor`. These normally are accessed via the `tex.nest` table:

```
tex.nest[tex.nest.ptr].prevdepth = p  
tex.nest[tex.nest.ptr].spacefactor = s
```

However, the following also works:

```
tex.prevdepth = p  
tex.spacefactor = s
```

Keep in mind that when you mess with node lists directly at the Lua end you might need to update the top of the nesting stack's `prevdepth` explicitly as there is no way Lua \TeX can guess your intentions. By using the accessor in the `tex` tables, you get and set the values at the top of the nesting stack.

10.3.2.3 Direction parameters

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



| | | |
|--------------------------|--------------------------|--------------------------|
| <code>tex.bodydir</code> | <code>tex.pagedir</code> | <code>tex.textdir</code> |
| <code>tex.mathdir</code> | <code>tex.pardir</code> | |

10.3.2.4 Glue parameters

The glue parameters accept and return a userdata object that represents a `glue_spec` node.

| | | |
|--|------------------------------|-------------------------------|
| <code>tex.abovedisplayshortskip</code> | <code>tex.leftskip</code> | <code>tex.spaceskip</code> |
| <code>tex.abovedisplayskip</code> | <code>tex.lineskip</code> | <code>tex.splittopskip</code> |
| <code>tex.baselineskip</code> | <code>tex.parfillskip</code> | <code>tex.tabskip</code> |
| <code>tex.belowdisplayshortskip</code> | <code>tex.parskip</code> | <code>tex.topskip</code> |
| <code>tex.belowdisplayskip</code> | <code>tex.rightskip</code> | <code>tex.xspaceskip</code> |

10.3.2.5 Muglue parameters

All muglue parameters are to be used read-only and return a Lua string.

| | | |
|----------------------------|------------------------------|-----------------------------|
| <code>tex.medmuskip</code> | <code>tex.thickmuskip</code> | <code>tex.thinmuskip</code> |
|----------------------------|------------------------------|-----------------------------|

10.3.2.6 Tokenlist parameters

The tokenlist parameters 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). It follows that assigning to some of these, like `'tex.output'`, is actually useless, but it feels bad to make exceptions in view of a coming extension that will accept full-blown token strings.

| | | |
|-------------------------------|----------------------------|----------------------------|
| <code>tex.errhelp</code> | <code>tex.everyhbox</code> | <code>tex.everyvbox</code> |
| <code>tex.everycr</code> | <code>tex.everyjob</code> | <code>tex.output</code> |
| <code>tex.everydisplay</code> | <code>tex.everymath</code> | |
| <code>tex.everyeof</code> | <code>tex.everypar</code> | |

10.3.3 Convert commands

All 'convert' commands are read-only and return a Lua string. The supported commands at this moment are:

| | |
|---------------------------------|---|
| <code>tex.eTeXVersion</code> | <code>tex.fontname(number)</code> |
| <code>tex.eTeXrevision</code> | <code>tex.uniformdeviate(number)</code> |
| <code>tex.formatname</code> | <code>tex.number(number)</code> |
| <code>tex.jobname</code> | <code>tex.romannumeral(number)</code> |
| <code>tex.luatexbanner</code> | <code>tex.fontidentifier(number)</code> |
| <code>tex.luatexrevision</code> | |

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, as well as the ones that require only a simple



numeric value. The special (Lua-only) case of `tex.fontidentifier` returns the `csname` string that matches a font id number (if there is one).

10.3.4 Last item commands

All ‘last item’ commands are read-only and return a number. The supported commands at this moment are:

| | | |
|-------------------------------|------------------------------------|-----------------------------------|
| <code>tex.lastpenalty</code> | <code>tex.lastypos</code> | <code>tex.currentgrouptype</code> |
| <code>tex.lastkern</code> | <code>tex.randomseed</code> | <code>tex.currentiflevel</code> |
| <code>tex.lastskip</code> | <code>tex.luatexversion</code> | <code>tex.currentiftype</code> |
| <code>tex.lastnodetype</code> | <code>tex.eTeXminorversion</code> | <code>tex.currentifbranch</code> |
| <code>tex.inputlineno</code> | <code>tex.eTeXversion</code> | |
| <code>tex.lastxpos</code> | <code>tex.currentgrouplevel</code> | |

10.3.5 Accessing registers: `set*`, `get*` and `is*`

\TeX 's attributes (`\attribute`), counters (`\count`), dimensions (`\dimen`), skips (`\skip`, `\muskip`) and token (`\toks`) registers can be accessed and written to using two times five virtual sub-tables of the `tex` table:

| | | |
|----------------------------|-------------------------|-------------------------|
| <code>tex.attribute</code> | <code>tex.skip</code> | <code>tex.muglue</code> |
| <code>tex.count</code> | <code>tex.glue</code> | <code>tex.toks</code> |
| <code>tex.dimen</code> | <code>tex.muskip</code> | |

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

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

In this case, Lua \TeX looks up the value for you on the fly. You have to use a valid `\countdef` (or `\attributedef`, or `\dimendef`, or `\skipdef`, 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 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).
- ▶ The skip registers accept and return `glue_spec` userdata node objects (see the description of the node interface elsewhere in this manual).
- ▶ The glue registers are just skip registers but instead of userdata are verbose.
- ▶ Like the counts, the attribute registers accept and return Lua numbers.



As an alternative to array addressing, there are also accessor functions defined for all cases, for example, here is the set of possibilities for `\skip` registers:

```
tex.setskip (["global",] <number> n, <node> s)
tex.setskip (["global",] <string> s, <node> s)
<node> s = tex.getskip (<number> n)
<node> s = tex.getskip (<string> s)
```

We have similar setters for `count`, `dimen`, `muskip`, and `toks`. Counters and `dimen` are represented by numbers, `skips` and `muskip`s by nodes, and `toks` by strings.

Again the glue variants are not using the `glue_spec` userdata nodes. The `setglue` function accepts upto 5 arguments: `width`, `stretch`, `shrink`, `stretch order` and `shrink order`. If you pass no values or if a value is not a number the corresponding property will become a zero. The `getglue` function reports all properties, unless the second argument is `false` in which case only the `width` is returned.

Here is an example using a threesome:

```
local d = tex.getdimen("foo")
if tex.isdimen("bar") then
    tex.setdimen("bar",d)
end
```

There are six extra `skip` (glue) related helpers:

```
tex.setglue (["global"], <number> n,
    width, stretch, shrink, stretch_order, shrink_order)
tex.setglue (["global"], <string> s,
    width, stretch, shrink, stretch_order, shrink_order)
width, stretch, shrink, stretch_order, shrink_order =
    tex.getglue (<number> n)
width, stretch, shrink, stretch_order, shrink_order =
    tex.getglue (<string> s)
```

The other two are `tex.setmuglue` and `tex.getmuglue`.

There are such helpers for `dimen`, `count`, `skip`, `muskip`, `box` and `attribute` registers but the glue ones are special because they have to deal with more properties.

As with the general `get` and `set` function discussed before, for the `skip` registers `getskip` returns a node and `getglue` returns numbers, while `setskip` accepts a node and `setglue` expects upto five numbers. Again, when you pass `false` as second argument to `getglue` you only get the `width` returned. The same is true for the `mu` variants `getmuskip`, `setmuskip`, `getmuskip` and `setmuskip`.

For `tokens` registers we have an alternative where a `catcode` table is specified:

```
tex.scantoks(0,3,"$e=mc^2$")
tex.scantoks("global",0,"$\int\limits^1_2$")
```

In the function-based interface, it is possible to define values globally by using the string `global` as the first function argument.



There is a dedicated getter for marks: `getmark` that takes two arguments. The first argument is one of `top`, `bottom`, `first`, `splitbottom` or `splitfirst`, and the second argument is a marks class number. When no arguments are given the current maximum number of classes is returned.

10.3.6 Character code registers: `[get|set]*code[s]`

T_EX's character code tables (`\lccode`, `\uccode`, `\sfcode`, `\catcode`, `\mathcode`, `\delcode`) can be accessed and written to using six virtual subtables of the `tex` table

```
tex.lccode          tex.sfcode          tex.mathcode
tex.uccode          tex.catcode        tex.delcode
```

The function call interfaces are roughly as above, but there are a few twists. `sfcodes` are the simple ones:

```
tex.setsfcode (["global",] <number> n, <number> s)
<number> s = tex.getsfcode (<number> n)
```

The function call interface for `lccode` and `uccode` additionally allows you to set the associated sibling at the same time:

```
tex.setlccode (["global"], <number> n, <number> lc)
tex.setlccode (["global"], <number> n, <number> lc, <number> uc)
<number> lc = tex.getlccode (<number> n)
tex.setuccode (["global"], <number> n, <number> uc)
tex.setuccode (["global"], <number> n, <number> uc, <number> lc)
<number> uc = tex.getuccode (<number> n)
```

The function call interface for `catcode` also allows you to specify a category table to use on assignment or on query (default in both cases is the current one):

```
tex.setcatcode (["global"], <number> n, <number> c)
tex.setcatcode (["global"], <number> cattable, <number> n, <number> c)
<number> lc = tex.getcatcode (<number> n)
<number> lc = tex.getcatcode (<number> cattable, <number> n)
```

The interfaces for `delcode` and `mathcode` use small array tables to set and retrieve values:

```
tex.setmathcode (["global"], <number> n, <table> mval )
<table> mval = tex.getmathcode (<number> n)
tex.setdelcode (["global"], <number> n, <table> dval )
<table> dval = tex.getdelcode (<number> n)
```

Where the table for `mathcode` is an array of 3 numbers, like this:

```
{
  <number> class,
```



```

    <number> family,
    <number> character
}

```

And the table for `delcode` is an array with 4 numbers, like this:

```

{
    <number> small_fam,
    <number> small_char,
    <number> large_fam,
    <number> large_char
}

```

You can also avoid the table:

```

tex.setmathcode (["global"], <number> n, <number> class,
    <number> family, <number> character)
class, family, char =
    tex.getmathcodes (<number> n)
tex.setdelcode (["global"], <number> n, <number> smallfam,
    <number> smallchar, <number> largefam, <number> largechar)
smallfam, smallchar, largefam, largechar =
    tex.getdelcodes (<number> n)

```

Normally, the third and fourth values in a delimiter code assignment will be zero according to `\Udelcode` usage, but the returned table can have values there (if the delimiter code was set using `\delcode`, for example). Unset `delcode`'s can be recognized because `dval[1]` is `-1`.

10.3.7 Box registers: `[get|set]box`

It is possible to set and query actual boxes, coming for instance from `\hbox`, `\vbox` or `\vtop`, using the node interface as defined in the node library:

```
tex.box
```

for array access, or

```

tex.setbox(["global",] <number> n, <node> s)
tex.setbox(["global",] <string> cs, <node> s)
<node> n = tex.getbox(<number> n)
<node> n = tex.getbox(<string> cs)

```

for function-based access. In the function-based interface, it is possible to define values globally by using the string `global` as the first function argument.

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 T_EX 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])
```

10.3.8 Reusing boxes: `[use|save]boxresource` and `getboxresourcedimensions`

The following function will register a box for reuse (this is modelled after so called xforms in pdf). You can (re)use the box with `\useboxresource` or by creating a rule node with subtype 2.

```
local index = tex.saveboxresource(n,attributes,resources,immediate,type,margin)
```

The optional second and third arguments are strings, the fourth is a boolean. The fifth argument is a type. When set to non-zero the `/Type` entry is omitted. A value of 1 or 3 still writes a `/BBox`, while 2 or 3 will write a `/Matrix`. The sixth argument is the (virtual) margin that extends beyond the effective boundingbox as seen by T_EX. Instead of a box number one can also pass a `[h|v]list` node.

You can generate the reference (a rule type) with:

```
local reused = tex.useboxresource(n,wd,ht,dp)
```

The dimensions are optional and the final ones are returned as extra values. The following is just a bonus (no dimensions returned means that the resource is unknown):

```
local w, h, d, m = tex.getboxresourcedimensions(n)
```

This returns the width, height, depth and margin of the resource.

10.3.9 `triggerbuildpage`

You should not expect too much from the `triggerbuildpage` helpers because often T_EX doesn't do much if it thinks nothing has to be done, but it might be useful for some applications. It just does as it says it calls the internal function that build a page, given that there is something to build.

10.3.10 `splitbox`

You can split a box:

```
local vlist = tex.splitbox(n,height,mode)
```

The remainder is kept in the original box and a packaged vlist is returned. This operation is comparable to the `\vsplit` operation. The mode can be `additional` or `exactly` and concerns the split off box.



10.3.11 Accessing math parameters: [get|set]math

It is possible to set and query the internal math parameters using:

```
tex.setmath(["global",] <string> n, <string> t, <number> n)
<number> n = tex.getmath(<string> n, <string> t)
```

As before an optional first parameter `global` indicates a global assignment.

The first string is the parameter name minus the leading ‘Umath’, and the second string is the style name minus the trailing ‘style’. Just to be complete, the values for the math parameter name are:

| | | | |
|---------------------|---------------------|--------------------|-------------------|
| quad | axis | operatorsize | |
| overbarkern | overbarrule | overbarvgap | |
| underbarkern | underbarrule | underbarvgap | |
| radicalkern | radicalrule | radicalvgap | |
| radicaldegreebefore | radicaldegreeafter | radicaldegreeraise | |
| stackvgap | stacknumup | stackdenomdown | |
| fractionrule | fractionnumvgap | fractionnumup | |
| fractiondenomvgap | fractiondenomdown | fractiondelsize | |
| limitabovevgap | limitabovebgap | limitabovekern | |
| limitbelowvgap | limitbelowbgap | limitbelowkern | |
| underdelimitervgap | underdelimiterbgap | | |
| overdelimitervgap | overdelimiterbgap | | |
| subshiftdrop | supshiftdrop | subshiftdown | |
| subsupshiftdown | subtopmax | supshiftup | |
| supbottommin | supsubbottommax | subsupvgap | |
| spaceafterscript | connectoroverlapmin | | |
| ordordspacing | ordopspacing | ordbinspacing | ordrelspacing |
| ordopenspacing | ordclosespacing | ordpunctspacing | ordinnerspacing |
| opordspacing | opopspacing | opbinspacing | oprelspacing |
| opopenspacing | opclosespacing | oppunctspacing | opinnerspacing |
| binordspacing | binopspacing | binbinspacing | binrelspacing |
| binopenspacing | binclosespacing | binpunctspacing | bininnerspacing |
| relordspacing | relopspacing | relbinspacing | relrelspacing |
| relopenspacing | relclosespacing | relpunctspacing | relinnerspacing |
| openordspacing | openopspacing | openbinspacing | openrelspacing |
| openopenspacing | openclosespacing | openpunctspacing | openinnerspacing |
| closeordspacing | closeopspacing | closebinspacing | closerelspacing |
| closeopenspacing | closeclosespacing | closepunctspacing | closeinnerspacing |
| punctordspacing | punctopspacing | punctbinspacing | punctrelspacing |
| punctopenspacing | punctclosespacing | punctpunctspacing | punctinnerspacing |
| innerordspacing | inneropspacing | innerbinspacing | innerrelspacing |
| inneropenspacing | innerclosespacing | innerpunctspacing | innerinnerspacing |

The values for the style parameter are:

display crampeddisplay



```
text          crampedtext
script        crampedscript
scriptscript crampedscriptscript
```

The value is either a number (representing a dimension or number) or a glue spec node representing a muskip for `ordordspacing` and similar spacing parameters.

10.3.12 Special list heads: `[get|set]list`

The virtual table `tex.lists` contains the set of internal registers that keep track of building page lists.

| FIELD | EXPLANATION |
|----------------------------------|--|
| <code>page_ins_head</code> | circular list of pending insertions |
| <code>contrib_head</code> | the recent contributions |
| <code>page_head</code> | the current page content |
| <code>hold_head</code> | used for held-over items for next page |
| <code>adjust_head</code> | head of the current <code>\vadjust</code> list |
| <code>pre_adjust_head</code> | head of the current <code>\vadjust pre</code> list |
| <code>page_discards_head</code> | head of the discarded items of a page break |
| <code>split_discards_head</code> | head of the discarded items in a <code>vsplit</code> |

The getter and setter functions are `getlist` and `setlist`. You have to be careful with what you set as \TeX can have expectations with regards to how a list is constructed or in what state it is.

10.3.13 Semantic nest levels: `getnest` and `ptr`

The virtual table `nest` contains the currently active semantic nesting state. It has two main parts: a zero-based array of `userdata` for the semantic nest itself, and the numerical value `ptr`, which gives the highest available index. Neither the array items in `nest[]` nor `ptr` can be assigned to (as this would confuse the typesetting engine beyond repair), but you can assign to the individual values inside the array items, e.g. `tex.nest[tex.nest.ptr].prevdepth`.

`tex.nest[tex.nest.ptr]` is the current nest state, `nest[0]` the outermost (main vertical list) level. The getter function is `getnest`. You can pass a number (which gives you a list), nothing or `top`, which returns the topmost list, or the string `ptr` which gives you the index of the topmost list.

The known fields are:

| KEY | TYPE | MODES | EXPLANATION |
|-----------------------|--------|-------|---|
| <code>mode</code> | number | all | the meaning of these numbers depends on the engine and sometimes even the version; you can use <code>tex.getmodevalues()</code> to get the mapping: positive values signal vertical, horizontal and math mode, while negative values indicate inner and inline variants |
| <code>modeline</code> | number | all | source input line where this mode was entered in, negative inside the output routine |



| | | | |
|-------------|---------|-------|---|
| head | node | all | the head of the current list |
| tail | node | all | the tail of the current list |
| prevgraf | number | vmode | number of lines in the previous paragraph |
| prevdepth | number | vmode | depth of the previous paragraph |
| spacefactor | number | hmode | the current space factor |
| dirs | node | hmode | used for temporary storage by the line break algorithm |
| noad | node | mmode | used for temporary storage of a pending fraction numerator, for <code>\over</code> etc. |
| delimptr | node | mmode | used for temporary storage of the previous math delimiter, for <code>\middle</code> |
| mathdir | boolean | mmode | true when during math processing the <code>\mathdir</code> is not the same as the surrounding <code>\textdir</code> |
| mathstyle | number | mmode | the current <code>\mathstyle</code> |

10.3.14 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. The result of using these functions from inside callbacks is undefined at the moment.

10.3.14.1 print

```
tex.print(<string> s, ...)
tex.print(<number> n, <string> s, ...)
tex.print(<table> t)
tex.print(<number> n, <table> t)
```

Each string argument is treated by \TeX as a separate input line. If there is a table argument instead of a list of strings, this has to be a consecutive array of strings to print (the first non-string value will stop the printing process).

The optional parameter can be used to print the strings using the catcode regime defined by `\catcodetable n`. If `n` is `-1`, the currently active catcode regime is used. If `n` is `-2`, the resulting catcodes are the result of `\the \toks`: all category codes are 12 (other) except for the space character, that has category code 10 (space). Otherwise, 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 `\newlinechar` appended, all others do.

10.3.14.2 sprint

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



```
tex.sprint(<table> t)
tex.sprint(<number> n, <table> t)
```

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

- ▶ T_EX 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 T_EX itself from eating spaces as result of interpreting the line. For example, in

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

the space before `in between` will be gobbled as a result of the ‘normal’ scanning of `\relax`.

If there is a table argument instead of a list of strings, this has to be a consecutive array of strings to print (the first non-string value will stop the printing process).

The optional argument sets the catcode regime, as with `tex.print`. This influences the string arguments (or numbers turned into strings).

Although this needs to be used with care, you can also pass token or node userdata objects. These get injected into the stream. Tokens had best be valid tokens, while nodes need to be around when they get injected. Therefore it is important to realize the following:

- ▶ When you inject a token, you need to pass a valid token userdata object. This object will be collected by Lua when it no longer is referenced. When it gets printed to T_EX the token itself gets copied so there is no interference with the Lua garbage collection. You manage the object yourself. Because tokens are actually just numbers, there is no real extra overhead at the T_EX end.
- ▶ When you inject a node, you need to pass a valid node userdata object. The node related to the object will not be collected by Lua when it no longer is referenced. It lives on at the T_EX end in its own memory space. When it gets printed to T_EX the node reference is used assuming that node stays around. There is no Lua garbage collection involved. Again, you manage the object yourself. The node itself is freed when T_EX is done with it.

If you consider the last remark you might realize that we have a problem when a printed mix of strings, tokens and nodes is reused. Inside T_EX the sequence becomes a linked list of input buffers. So, `"123"` or `"\foo{123}"` gets read and parsed on the fly, while `<token userdata>` already is tokenized and effectively is a token list now. A `<node userdata>` is also tokenized into a token list but it has a reference to a real node. Normally this goes fine. But now assume that you store the whole lot in a macro: in that case the tokenized node can be flushed many times. But, after the first such flush the node is used and its memory freed. You can prevent this by using copies which is controlled by setting `\luacopyinputnodes` to a non-zero value. This is one of these fuzzy areas you have to live with if you really mess with these low level issues.

10.3.14.3 tprint

```
tex.tprint({<number> n, <string> s, ...}, {...})
```



This function is basically a shortcut for repeated calls to `tex.sprint(<number> n, <string> s, ...)`, once for each of the supplied argument tables.

10.3.14.4 `cprint`

This function takes a number indicating the to be used catcode, plus either a table of strings or an argument list of strings that will be pushed into the input stream.

```
tex.cprint( 1," 1: ${\\foo}") tex.print("\\par") -- a lot of \bgroup s
tex.cprint( 2," 2: ${\\foo}") tex.print("\\par") -- matching \egroup s
tex.cprint( 9," 9: ${\\foo}") tex.print("\\par") -- all get ignored
tex.cprint(10,"10: ${\\foo}") tex.print("\\par") -- all become spaces
tex.cprint(11,"11: ${\\foo}") tex.print("\\par") -- letters
tex.cprint(12,"12: ${\\foo}") tex.print("\\par") -- other characters
tex.cprint(14,"12: ${\\foo}") tex.print("\\par") -- comment triggers
```

10.3.14.5 `write`

```
tex.write(<string> s, ...)
tex.write(<table> t)
```

Each string argument is treated by $\text{T}_{\text{E}}\text{X}$ as a special kind of input line that makes it 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.

If there is a table argument instead of a list of strings, this has to be a consecutive array of strings to print (the first non-string value will stop the printing process).

10.3.15 Helper functions

10.3.15.1 `round`

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

Rounds Lua number `o`, and returns a number that is in the range of a valid $\text{T}_{\text{E}}\text{X}$ register value. If the number starts out of range, it generates a ‘number too big’ error as well.

10.3.15.2 `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 $\text{T}_{\text{E}}\text{X}$ 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 multiplied number(s) are of range, it generates ‘number too big’ error(s) as well.

Note: the precision of the output of this function will depend on your computer’s architecture and operating system, so use with care! An interface to LuaTeX’s internal, 100% portable scale function will be added at a later date.

10.3.15.3 number and romannumeral

These are the companions to the primitives `\number` and `\romannumeral`. They can be used like:

```
tex.print(tex.romannumeral(123))
```

10.3.15.4 fontidentifier and fontname

The first one returns the name only, the second one reports the size too.

```
tex.print(tex.fontidentifier(1))
tex.print(tex.fontname(1))
```

10.3.15.5 sp

```
<number> n = tex.sp(<number> o)
<number> n = tex.sp(<string> s)
```

Converts the number `o` or a string `s` that represents an explicit dimension into an integer number of scaled points.

For parsing the string, the same scanning and conversion rules are used that LuaTeX would use if it was scanning a dimension specifier in its TeX-like input language (this includes generating errors for bad values), expect for the following:

1. only explicit values are allowed, control sequences are not handled
2. infinite dimension units (`fil...`) are forbidden
3. mu units do not generate an error (but may not be useful either)

10.3.15.6 error and show_context

```
tex.error(<string> s)
tex.error(<string> s, <table> help)
```

This creates an error somewhat like the combination of `\errhelp` and `\errmessage` would. During this error, deletions are disabled.

The array part of the help table has to contain strings, one for each line of error help.

In case of an error the `show_context` function will show the current context where we’re at (in the expansion).



10.3.15.7 run, finish

These two functions start the interpretations and force its end. A runs normally boils down to T_EX entering the so called main loop. A token is fetched and depending on it current meaning some actions takes place. Sometimes that actions comes immediately, sometimes more scanning is needed. Quite often tokens get pushed back into the input. This all means that the T_EX scanner is constantly pushing and popping input states, but in the end after all the action is done returns to the main loop.

10.3.15.8 runtoks

Because of the fact that T_EX is in a complex dance of expanding, dealing with fonts, typesetting paragraphs, messing around with boxes, building pages, and so on, you cannot easily run a nested T_EX run (read nested main loop). However, there is an option to force a local run with `runtoks`. The content of the given token list register gets expanded locally after which we return to where we triggered this expansion, at the Lua end. Instead a function can get passed that does some work. You have to make sure that at the end T_EX is in a sane state and this is not always trivial. A more complex mechanism would complicate T_EX itself (and probably also harm performance) so this simple local expansion loop has to do.

```
tex.runtoks(<token register>)  
tex.runtoks(<lua function>)
```

When the `\tracingnesting` parameter is set to a value larger than 2 some information is reported about the state of the local loop.

This function has two optional arguments in case a token register is passed:

```
tex.runtoks(<token register>,force,grouped)
```

Inside for instance an `\edef` the `runtoks` function behaves (at least tries to) like it were an `\the`. This prevents unwanted side effects: normally in such a definition tokens remain tokens and (for instance) characters don't become nodes. With the second argument you can force the local main loop, no matter what. The third argument adds a level of grouping.

You can quit the local loop with `\endlocalcontrol` or from the Lua end with `tex.quittoks`. In that case you end one level up! Of course in the end that can mean that you arrive at the main level in which case an extra end will trigger a redundancy warning (not an abort!).

10.3.15.9 forcehmode

An example of a (possible error triggering) complication is that T_EX expects to be in some state, say horizontal mode, and you have to make sure it is when you start feeding back something from Lua into T_EX. Normally a user will not run into issues but when you start writing tokens or nodes or have a nested run there can be situations that you need to run `forcehmode`. There is no recipe for this and intercepting possible cases would weaken LuaT_EX's flexibility.

10.3.15.10 hashtokens

```
for i,v in pairs (tex.hashtokens()) do ... end
```



Returns a list of names. This can be useful for debugging, but note that this also reports control sequences that may be unreachable at this moment due to local redefinitions: it is strictly a dump of the hash table. You can use `token.create` to inspect properties, for instance when the command key in a created table equals 123, you have the `cmdname` value `undefined_cs`.

10.3.15.11 `definefont`

```
tex.definefont(<string> csname, <number> fontid)
tex.definefont(<boolean> global, <string> csname, <number> fontid)
```

Associates `csname` with the internal font number `fontid`. The definition is global if (and only if) `global` is specified and true (the setting of `globaldefs` is not taken into account).

10.3.16 Functions for dealing with primitives

10.3.16.1 `enableprimitives`

```
tex.enableprimitives(<string> prefix, <table> primitive names)
```

This function accepts a prefix string and an array of primitive names. For each combination of ‘prefix’ and ‘name’, the `tex.enableprimitives` first verifies that ‘name’ is an actual primitive (it must be returned by one of the `tex.extraprimitives` calls explained below, or part of `TEX82`, or `\directlua`). If it is not, `tex.enableprimitives` does nothing and skips to the next pair.

But if it is, then it will construct a `csname` variable by concatenating the ‘prefix’ and ‘name’, unless the ‘prefix’ is already the actual prefix of ‘name’. In the latter case, it will discard the ‘prefix’, and just use ‘name’.

Then it will check for the existence of the constructed `csname`. If the `csname` is currently undefined (note: that is not the same as `\relax`), it will globally define the `csname` to have the meaning: run code belonging to the primitive ‘name’. If for some reason the `csname` is already defined, it does nothing and tries the next pair.

An example:

```
tex.enableprimitives('LuaTeX', {'formatname'})
```

will define `\LuaTeXformatname` with the same intrinsic meaning as the documented primitive `\formatname`, provided that the control sequences `\LuaTeXformatname` is currently undefined.

When `LuaTEX` is run with `--ini` only the `TEX82` primitives and `\directlua` are available, so no extra primitives **at all**.

If you want to have all the new functionality available using their default names, as it is now, you will have to add

```
\ifx\directlua\undefined \else
  \directlua {tex.enableprimitives('',tex.extraprimitives ())}
\fi
```



near the beginning of your format generation file. Or you can choose different prefixes for different subsets, as you see fit.

Calling some form of `tex.enableprimitives` is highly important though, because if you do not, you will end up with a TeX82-lookalike that can run Lua code but not do much else. The defined csnames are (of course) saved in the format and will be available at runtime.

10.3.16.2 extraprimitives

```
<table> t = tex.extraprimitives(<string> s, ...)
```

This function returns a list of the primitives that originate from the engine(s) given by the requested string value(s). The possible values and their (current) return values are given in the following table. In addition the somewhat special primitives ‘\’, ‘/’ and ‘-’ are defined.

| NAME | VALUES |
|------|---|
| tex | Uleft Umiddle Uright above abovedisplayshortskip abovedisplayshortskip abovewithdelims accent adjdemerits advance afterassignment aftergroup atop atopwithdelims badness baselineskip batchmode begingroup belowdisplayshortskip belowdisplayshortskip binoppenalty botmark boundary box boxmaxdepth brokenpenalty catcode char chardef cleaders closein closeout clubpenalty copy count countdef cr crcr curname day deadcycles def defaultthyphenchar defaultskewchar deferred delcode delimiter delimiterfactor delimitershortfall dimen dimendef discretionary displayindent displaylimits displaystyle displaywidowpenalty displaywidth divide doublehyphendemerits dp dump edef else emergencystretch end endcurname endgroup endinput endlineskip eqno errhelp errmessage errorcontextlines errorstopmode escapechar everycr everydisplay everyhbox everyjob everymath everypar everyvbox exhyphenchar exhyphenpenalty expandafter fam fi finalhyphendemerits firstmark firstvalidlanguage floatingpenalty font fontdimen fontname futurelet gdef glet global globaldefs halign hangafter hangingindent hbadness hbox hfil hfill hfillneg hfuzz hoffset holdinginserts hpack hrule hsize hskip hss ht hyphenation hyphenchar hyphenpenalty if ifcase ifcat ifdim ifeof iffalse ifhbox ifhmode ifinner ifmmode ifnum ifodd iftrue ifvbox ifvmode ifvoid ifx ignorespaces immediate indent input inputlineno insertinsertpenalties interlinepenalty jobname kern language lastbox lastkern lastpenalty lastskip lcode leaders left leftthyphenmin leftskip leqno let limits linepenalty lineskip lineskiplimit long looseness lower lowercase mag mark mathaccent mathbin mathchar mathchardef mathchoice mathclose mathcode mathinner mathop mathopen mathord mathpunct mathrel mathsurround maxdeadcycles maxdepth meaning medmuskip message middle mkern month moveleft moveright mskip multiply muskip muskipdef newlinechar noalign noboundary noexpand noindent nolimits nonscript nonstopmode nulldelimiterspace nullfont number omit openin openout or outer output outputpenalty over overfullrule overline overwithdelims pagedepth pagefillllstretch pagefillstretch pagefillstretch pagegoal pageshrink pagestretch pagetotal par parfillskip parindent parshape parskip patterns pausing penalty postdisplaypenalty predisplaypenalty predisplaysize pretolerance prevdepth prevgraf protrusionboundary radical raise |



read relax relpenalty right righthyphenmin rightskip romannumeral script-
font scriptscriptfont scriptscriptstyle scriptspace scriptstyle scrollmode
setbox setlanguage sfcodes shipout show showbox showboxbreadth showboxdepth
showlists showstream showthe skewchar skip skipdef spacefactor spaceskip span
special splitbotmark splitfirstmark splitmaxdepth splittopskip string tab-
skip textfont textstyle the thickmuskip thinmuskip time toks toksdef toler-
ance topmark topskip tpack tracingcommands tracinglostchars tracingmacros
tracingonline tracingoutput tracingpages tracingparagraphs tracingrestores
tracingstats uccode uchyph underline unhbox unhcopy unkern unpenalty unskip
unvbox unvcopy uppercase vadjust valign vbadness vbox vcenter vfil vfill vfil-
neg vfuzz voffset vpack vrule vsize vskip vsplit vss vtop wd widowpenalty word-
boundary write xdef xleaders xspaceskip year

core directlua

etex botmarks clubpenalties currentgrouplevel currentgrouptype currentifbranch
currentiflevel currentifttype detokenize dimexpr displaywidowpenalties
eTeXVersion eTeXminorversion eTeXrevision eTeXversion everyeof firstmarks
fontcharhp fontcharht fontcharic fontcharwd glueexpr glueshrink glueshrinko-
rder gluestretch gluestretchorder gluetomu ifcsname ifdefined iffontchar ig-
noreprimitiveerror interactionmode interlinepenalties lastlinefit lastnode-
type marks muexpr mutogluem numexpr pagediscards parshapedimen parshapeindent
parshapelength partokencontext partokenname predisplaydirection protected
readline savinghyphcodes savingvdiscards scantokens showgroups showifs show-
tokens splitbotmarks splitdiscards splitfirstmarks topmarks tracingassigns
tracinggroups tracingifs tracingnesting tracingscantokens unexpanded unless
widowpenalties

luatex Uchar Udelcode Udelcodenum Udelimiter Udelimiterover Udelimiterunder Uhex-
tensible Umathaccent Umathaxis Umathbinbinspacing Umathbinclonespacing
Umathbininnerspacing Umathbinopenspacing Umathbinopspacing Umathbi-
nordspacing Umathbinpunctspacing Umathbinrelspacing Umathchar Umath-
charclass Umathchardef Umathcharfam Umathcharnum Umathcharnumdef Umath-
charslot Umathclosebinspacing Umathcloseclonespacing Umathcloseinnerspac-
ing Umathcloseopenspacing Umathcloseopspacing Umathcloseordspacing Umath-
closepunctspacing Umathcloserelspacing Umathcode Umathcodenum Umathcon-
nectoroverlapmin Umathfractiondelsize Umathfractiondenomdown Umathfrac-
tiondenomvgap Umathfractionnumup Umathfractionnumvgap Umathfractionrule
Umathinnerbinspacing Umathinnerclonespacing Umathinnerinnerspacing Umath-
inneropenspacing Umathinneropspacing Umathinnerordspacing Umathinner-
punctspacing Umathinnerrelspacing Umathlimitabovebgap Umathlimitabovek-
ern Umathlimitabovevgap Umathlimitbelowbgap Umathlimitbelowkern Umathlim-
itbelowvgap Umathnolimitsubfactor Umathnolimitsupfactor Umathopbinspac-
ing Umathopclonespacing Umathopenbinspacing Umathopenclonespacing Umath-
openinnerspacing Umathopenopenspacing Umathopenopspacing Umathopenordspac-
ing Umathopenpunctspacing Umathopenrelspacing Umathoperatorsize Umathopin-
nerspacing Umathopopenspacing Umathopopspacing Umathopordspacing Umath-
oppunctspacing Umathoprelspacing Umathordbinspacing Umathordclonespacing
Umathordinnerspacing Umathordopenspacing Umathordopspacing Umathor-



dordspacing Umathordpunctspacing Umathordrelspacing Umathoverbarkern Umath-
overbarrule Umathoverbarvgap Umathoverdelimiterbgap Umathoverdelimiter-
vgap Umathpunctbinspacing Umathpunctclosespacing Umathpunctinnerspacing
Umathpunctopenspacing Umathpunctospacing Umathpunctordspacing Umathpunct-
punctspacing Umathpunctrelspacing Umathquad Umathradicaldegreeafter Umath-
radicaldegreebefore Umathradicaldegreeraise Umathradicalkern Umathradical-
rule Umathradicalvgap Umathrelbinspacing Umathrelclosespacing Umathrelin-
nerspacing Umathreloppenspacing Umathreloppspacing Umathrelordspacing Umath-
relpunctspacing Umathrelrelspacing Umathskewedfractionhgap Umathskewed-
fractionvgap Umathspaceafterscript Umathstackdenomdown Umathstacknumup
Umathstackvgap Umathsubshiftdown Umathsubshiftdrop Umathsubsupshiftdown
Umathsubsupvgap Umathsubtopmax Umathsupbottommin Umathsupshiftdrop Umath-
supshiftdown Umathsupsubbottommax Umathunderbarkern Umathunderbarrule Umath-
underbarvgap Umathunderdelimiterbgap Umathunderdelimitervgap Unosubscript
Unosuperscript Uoverdelimiter Uradical Uroot Uskewed Uskewedwithdelims Us-
tack Ustartdisplaymath Ustartmath Ustopdisplaymath Ustopmath Usubscript
Usuperscript Uunderdelimiter Uvextensible adjustspacing alignmark aligntab
attribute attributedef automaticdiscretionary automatichyphenmode auto-
matichyphenpenalty beginscname bodydir bodydirection boxdir boxdirection
breakafterdirmode catcodetable clearmarks compoundhyphenmode copyfont
crampeddisplaystyle crampedscriptscriptstyle crampedscriptstyle cramped-
textstyle csstring discretionaryligaturemode draftmode dviextension dv-
ifedback dvivariable eTeXglueshrinkorder eTeXgluestretchorder ecode end-
localcontrol etoksapp etokspre exceptionpenalty expanded expandglyphsin-
font explicitdiscretionary explicithyphenpenalty fixupboxesmode fontid
formatname gleaders glyphdimensionsmode gtoksapp gtokspre hjcode hyphen-
ationbounds hyphenationmin hyphenpenaltymode ifabsdim ifabsnum ifcondition
ifincsname ifprimitive ignoreligaturesinfont immediateassigned immediate-
assignment initcatcodetable insertht lastnamedcs lastsavedboxresourceindex
lastsavedimageresourceindex lastsavedimageresourcepages lastxpos lastypos
latelua lateluafunction leftghost leftmarginkern letcharcode letterspace-
font linedir linedirection localbrokenpenalty localinterlinepenalty lo-
calleftbox localrightbox lpcode luabytecode luabytecodecall luacopyinputn-
odes luaedef luaescapestring luafunction luafunctioncall luatexbanner lua-
texrevision luatexversion mathdefaultsmode mathdelimitersmode mathdir math-
direction mathdisplayskipmode mathemptydisplaymode matheqdirmode matheqno-
gapstep mathflattenmode mathitalicsmode mathnolimitsmode mathoption math-
penaltiesmode mathrulesfam mathrulesmode mathrulethicknessmode mathscript-
boxmode mathscriptcharmode mathscriptsmode mathstyle mathsurroundmode math-
surroundskip nohrule nokerns noligs normaldeviate nospaces novrule outputbox
outputmode pagebottomoffset pagedir pagedirection pageheight pageleftoff-
set pagerightoffset pagetopoffset pagewidth pardir pardirection pdfextension
pdffeedback pdfvariable postexhyphenchar posthyphenchar prebinoppenalty
predisplaygapfactor preexhyphenchar prehyphenchar prerelpenalty primitive
protrudechars pxdimen quitvmode randomseed rightghost rightmarginkern rp-
code saveboxresource savecatcodetable saveimageresource savepos scantexto-



kens setfontid setrandomseed shapemode suppressfontnotfounderror suppressifcsnameerror suppresslongerror suppressmathparerror suppressoutererror suppressprimitiveerror syntex tagcode textdir textdirection toksapp tok-spre tracingfonts uniformdeviate useboxresource useimageresource variable-fam xtoksapp xtokspre

Note that `luatex` does not contain `directlua`, as that is considered to be a core primitive, along with all the \TeX 82 primitives, so it is part of the list that is returned from 'core'.

Running `tex.extraprimitives` will give you the complete list of primitives -ini startup. It is exactly equivalent to `tex.extraprimitives("etex", "luatex")`.

10.3.16.3 primitives

```
<table> t = tex.primitives()
```

This function returns a list of all primitives that Lua \TeX knows about.

10.3.17 Core functionality interfaces

10.3.17.1 badness

```
<number> b = tex.badness(<number> t, <number> s)
```

This helper function is useful during linebreak calculations. `t` and `s` are scaled values; the function returns the badness for when total `t` is supposed to be made from amounts that sum to `s`. The returned number is a reasonable approximation of $100(t/s)^3$;

10.3.17.2 tex.resetparagraph

This function resets the parameters that \TeX normally resets when a new paragraph is seen.

10.3.17.3 linebreak

```
local <node> nodelist, <table> info =
  tex.linebreak(<node> listhead, <table> parameters)
```

The understood parameters are as follows:

| NAME | TYPE | EXPLANATION |
|--------------------------------|--------|-------------|
| <code>pardir</code> | string | |
| <code>pretolerance</code> | number | |
| <code>tracingparagraphs</code> | number | |
| <code>tolerance</code> | number | |
| <code>looseness</code> | number | |
| <code>hyphenpenalty</code> | number | |
| <code>exhyphenpenalty</code> | number | |



| | | |
|--------------------|-----------------|---|
| pdfadjustspacing | number | |
| adjdemerits | number | |
| pdfprotrudechars | number | |
| linepenalty | number | |
| lastlinefit | number | |
| doublehyphdemerits | number | |
| finalhyphdemerits | number | |
| hangafter | number | |
| interlinepenalty | number or table | if a table, then it is an array like <code>\interlinepenalties</code> |
| clubpenalty | number or table | if a table, then it is an array like <code>\clubpenalties</code> |
| widowpenalty | number or table | if a table, then it is an array like <code>\widowpenalties</code> |
| brokenpenalty | number | |
| emergencystretch | number | in scaled points |
| hangindent | number | in scaled points |
| hsize | number | in scaled points |
| leftskip | glue_spec node | |
| rightskip | glue_spec node | |
| parshape | table | |

Note that there is no interface for `\displaywidowpenalties`, you have to pass the right choice for `widowpenalties` yourself.

It is your own job to make sure that `listhead` is a proper paragraph list: this function does not add any nodes to it. To be exact, if you want to replace the core line breaking, you may have to do the following (when you are not actually working in the `pre_linebreak_filter` or `linebreak_filter` callbacks, or when the original list starting at `listhead` was generated in horizontal mode):

- ▶ add an ‘indent box’ and perhaps a `local_par` node at the start (only if you need them)
- ▶ replace any found final glue by an infinite penalty (or add such a penalty, if the last node is not a glue)
- ▶ add a glue node for the `\parfillskip` after that penalty node
- ▶ make sure all the `prev` pointers are OK

The result is a node list, it still needs to be `vpacked` if you want to assign it to a `\vbox`. The returned info table contains four values that are all numbers:

| NAME | EXPLANATION |
|------------------------|--|
| <code>prevdepth</code> | depth of the last line in the broken paragraph |
| <code>prevgraf</code> | number of lines in the broken paragraph |
| <code>looseness</code> | the actual looseness value in the broken paragraph |
| <code>demerits</code> | the total demerits of the chosen solution |

Note there are a few things you cannot interface using this function: You cannot influence font expansion other than via `pdfadjustspacing`, because the settings for that take place elsewhere. The same is true for `hbadness` and `hfuzz` etc. All these are in the `hpack` routine, and that fetches its own variables via `globals`.



10.3.17.4 shipout

```
tex.shipout(<number> n)
```

Ships out box number n to the output file, and clears the box register.

10.3.17.5 getpagestate

This helper reports the current page state: `empty`, `box_there` or `inserts_only` as integer value.

10.3.17.6 getlocallevel

This integer reports the current level of the local loop. It's only useful for debugging and the (relative state) numbers can change with the implementation.

10.3.18 Randomizers

For practical reasons Lua \TeX has its own random number generator. The original Lua random function is available as `tex.lua_math_random`. You can initialize with a new seed with `init_rand` (`lua_math_randomseed` is equivalent to this one).

There are three generators: `normal_rand` (no argument is used), `uniform_rand` (takes a number that will get rounded before being used) and `uniformdeviate` which behaves like the primitive and expects a scaled integer, so

```
tex.print(tex.uniformdeviate(65536)/65536)
```

will give a random number between zero and one.

10.3.19 Functions related to synctex

The next helpers only make sense when you implement your own synctex logic. Keep in mind that the library used in editors assumes a certain logic and is geared for plain and L \TeX , so after a decade users expect a certain behaviour.

| NAME | EXPLANATION |
|-----------------------------------|--|
| <code>set_synctex_mode</code> | 0 is the default and used normal synctex logic, 1 uses the values set by the next helpers while 2 also sets these for glyph nodes; 3 sets glyphs and glue and 4 sets only glyphs |
| <code>set_synctex_tag</code> | set the current tag (file) value (obeys save stack) |
| <code>set_synctex_line</code> | set the current line value (obeys save stack) |
| <code>set_synctex_no_files</code> | disable synctex file logging |
| <code>get_synctex_mode</code> | returns the current mode (for values see above) |
| <code>get_synctex_tag</code> | get the currently set value of tag (file) |
| <code>get_synctex_line</code> | get the currently set value of line |
| <code>force_synctex_tag</code> | overload the tag (file) value (0 resets) |
| <code>force_synctex_line</code> | overload the line value (0 resets) |



The last one is somewhat special. Due to the way files are registered in SyncTeX we need to explicitly disable that feature if we provide our own alternative if we want to avoid that overhead. Passing a value of 1 disables registering.

10.4 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 |
|-----------------------|---------|---------|--|
| kpse_init | boolean | true | false totally disables kpathsea initialisation, and enables interpretation of the following numeric key-value pairs. (only ever unset this if you implement <i>all</i> file find callbacks!) |
| shell_escape | string | 'f' | Use 'y' or 't' or 'l' to enable <code>\write 18</code> unconditionally, 'p' to enable the commands that are listed in <code>shell_escape_commands</code> |
| shell_escape_commands | string | | Comma-separated list of command names that may be executed by <code>\write 18</code> even if <code>shell_escape</code> is set to 'p'. Do <i>not</i> use spaces around commas, separate any required command arguments by using a space, and use the ascii double quote (") for any needed argument or path quoting |
| 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 |
| hash_extra | number | 0 | cf. web2c docs |
| pk_dpi | number | 72 | cf. web2c docs |
| trace_file_names | boolean | true | false disables TeX's normal file open-close feedback (the assumption is that callbacks will take care of that) |
| trace_extra_newline | boolean | false | adds an extra newline in <code>\tracingmacros</code> |
| file_line_error | boolean | false | do <code>file:line</code> 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 command line, this key will be tested first instead of simply quitting |



| | | |
|-----------------------|---------|--|
| jobname | string | if no input file name was given on the command line, this key will be tested first instead of simply giving up |
| level_chr | number | character to put in front of traced macros (see next value) |
| level_max | number | when larger than zero the input nesting level will be shown when <code>\tracingmacros</code> is set; levels above this value will be clipped with the level shown up front |
| check_dvi_total_pages | boolean | in dvi output mode, if true abort run when the number of pages exceeds 65535. This is the default behaviour. If false, the run goes on as is in T _E X. |
| texlua_img | boolean | if true, allows access to the <code>img</code> library in T _E X Lua mode. If false (the default), the <code>img</code> library is not available in T _E X Lua mode (as it was unconditionally for LuaT _E X versions prior to 1.22.0). Note that this setting is experimental and subject to be removed at any time, without notice. |

Note: the numeric values that match web2c parameters are only used if `kpse_init` is explicitly set to `false`. In all other cases, the normal values from `texmf.cnf` are used.

You can kick in your own nesting level visualizer, for instance:

```
callback.register("input_level_string",function(n)
  if tex.tracingmacros > 0 and tex.count.tracingstacklevels > 0 then
    if tex.tracingmacros > 1 then
      return "! " .. string.rep(">",n) .. " "
    end
  end
  return ""
end)
```

Or, in sync with other engines (not checked):

```
\directlua {
  callback.register("input_level_string", function(n)
    if tex.tracingmacros > 0 then
      local l = tex.count.tracingstacklevels
      if l > 0 then
        return string.rep("~",l) .. string.rep(".",n-l)
      end
    end
    return ""
  end)
}
```



10.5 The `texio` library

This library takes care of the low-level I/O interface: writing to the log file and/or console.

10.5.1 `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 explicitly to prevent Lua from interpreting the first string as the target.

10.5.2 `write_nl`

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

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

10.5.3 `setescape`

You can disable `^^` escaping of control characters by passing a value of zero.

10.5.4 `closeinput`

This function that should be used with care. It acts as `\endinput` but at the Lua end. You can use it to (sort of) force a jump back to \TeX . Normally a Lua will just collect prints and at the end bump an input level and flush these prints. This function can help you stay at the current level but you need to know what you're doing (or more precise: what \TeX is doing with input).

10.6 The `token` library

10.6.1 The scanner

The `token` library provides means to intercept the input and deal with it at the Lua level. The library provides a basic scanner infrastructure that can be used to write macros that accept a wide range of arguments. This interface is on purpose kept general and as performance is



quite ok. One can build additional parsers without too much overhead. It's up to macro package writers to see how they can benefit from this as the main principle behind LuaTeX is to provide a minimal set of tools and no solutions. The scanner functions are probably the most intriguing.

| FUNCTION | ARGUMENT | RESULT |
|-----------------------------|--------------------|--|
| <code>scan_keyword</code> | string | returns true if the given keyword is gobbled; as with the regular TeX keyword scanner this is case insensitive (and ascii based) |
| <code>scan_keywordcs</code> | string | returns true if the given keyword is gobbled; this variant is case sensitive and also suitable for utf8 |
| <code>scan_int</code> | | returns an integer |
| <code>scan_real</code> | | returns a number from e.g. 1, 1.1, .1 with optional collapsed signs |
| <code>scan_float</code> | | returns a number from e.g. 1, 1.1, .1, 1.1E10, , .1e-10 with optional collapsed signs |
| <code>scan_dimen</code> | infinity, mu-units | returns a number representing a dimension and or two numbers being the filler and order |
| <code>scan_glue</code> | mu-units | returns a glue spec node |
| <code>scan_toks</code> | definer, expand | returns a table of tokens tokens |
| <code>scan_code</code> | bitset | returns a character if its category is in the given bitset (representing catcodes) |
| <code>scan_string</code> | | returns a string given between {}, as <code>\macro</code> or as sequence of characters with catcode 11 or 12 |
| <code>scan_argument</code> | boolean | this one is similar to <code>scanstring</code> but also accepts a <code>\cs</code> |
| <code>scan_word</code> | | returns a sequence of characters with catcode 11 or 12 as string |
| <code>scan_csname</code> | | returns <code>foo</code> after scanning <code>\foo</code> |
| <code>scan_list</code> | | picks up a box specification and returns a <code>[h v]list</code> node |

The scanners can be considered stable apart from the one scanning for a token. The `scan_code` function takes an optional number, the keyword function a normal Lua string. The `infinity` boolean signals that we also permit `fill` as dimension and the `mu-units` flags the scanner that we expect math units. When scanning tokens we can indicate that we are defining a macro, in which case the result will also provide information about what arguments are expected and in the result this is separated from the meaning by a separator token. The `expand` flag determines if the list will be expanded.

The `scan_argument` function expands the given argument. When a braced argument is scanned, expansion can be prohibited by passing `false` (default is `true`). In case of a control sequence passing `false` will result in a one-level expansion (the meaning of the macro).

The string scanner scans for something between curly braces and expands on the way, or when it sees a control sequence it will return its meaning. Otherwise it will scan characters with catcode `letter` or `other`. So, given the following definition:

```
\def\bar{bar}
\def\foo{foo-\bar}
```

we get:



| NAME | RESULT | |
|---|----------------------|--------------------|
| <code>\directlua{token.scan_string(){foo}}</code> | <code>foo</code> | full expansion |
| <code>\directlua{token.scan_string()}foo</code> | <code>foo</code> | letters and others |
| <code>\directlua{token.scan_string()}\foo</code> | <code>foo-bar</code> | meaning |

The `\foo` case only gives the meaning, but one can pass an already expanded definition (`\edef'd`). In the case of the braced variant one can of course use the `\detokenize` and `\unexpanded` primitives since there we do expand.

The `scan_word` scanner can be used to implement for instance a number scanner:

```
function token.scan_number(base)
    return tonumber(token.scan_word(),base)
end
```

This scanner accepts any valid Lua number so it is a way to pick up floats in the input.

You can use the Lua interface as follows:

```
\directlua {
    function mymacro(n)
        ...
    end
}

\def\mymacro#1{%
    \directlua {
        mymacro(\number\dimexpr#1)
    }%
}
```

```
\mymacro{12pt}
\mymacro{\dimen0}
```

You can also do this:

```
\directlua {
    function mymacro()
        local d = token.scan_dimen()
        ...
    end
}

\def\mymacro{%
    \directlua {
        mymacro()
    }%
}

\mymacro 12pt
```



`\mymacro \dimen0`

It is quite clear from looking at the code what the first method needs as argument(s). For the second method you need to look at the Lua code to see what gets picked up. Instead of passing from T_EX to Lua we let Lua fetch from the input stream.

In the first case the input is tokenized and then turned into a string, then it is passed to Lua where it gets interpreted. In the second case only a function call gets interpreted but then the input is picked up by explicitly calling the scanner functions. These return proper Lua variables so no further conversion has to be done. This is more efficient but in practice (given what T_EX has to do) this effect should not be overestimated. For numbers and dimensions it saves a bit but for passing strings conversion to and from tokens has to be done anyway (although we can probably speed up the process in later versions if needed).

10.6.2 Picking up one token

The scanners look for a sequence. When you want to pick up one token from the input you use `get_next`. This creates a token with the (low level) properties as discussed next. This token is just the next one. If you want to enforce expansion first you can use `scan_token`. Internally tokens are characterized by a number that packs a lot of information. In order to access the bits of information a token is wrapped in a userdata object.

The `expand` function will trigger expansion of the next token in the input. This can be quite unpredictable but when you call it you probably know enough about T_EX not to be too worried about that. It basically is a call to the internal `expand` related function.

10.6.3 Creating tokens

The creator function can be used as follows:

```
local t = token.create("relax")
```

This gives back a token object that has the properties of the `\relax` primitive. The possible properties of tokens are:

| NAME | EXPLANATION |
|-------------------------|--|
| <code>command</code> | a number representing the internal command number |
| <code>cmdname</code> | the type of the command (for instance the catcode in case of a character or the classifier that determines the internal treatment) |
| <code>csname</code> | the associated control sequence (if applicable) |
| <code>id</code> | the unique id of the token |
| <code>tok</code> | the full token number as stored in T _E X |
| <code>active</code> | a boolean indicating the active state of the token |
| <code>expandable</code> | a boolean indicating if the token (macro) is expandable |
| <code>protected</code> | a boolean indicating if the token (macro) is protected |
| <code>mode</code> | a number either representing a character or another entity |
| <code>index</code> | a number running from 0x0000 upto 0xFFFF indicating a T _E X register index |



Alternatively you can use a getter `get_<fieldname>` to access a property of a token.

The numbers that represent a catcode are the same as in \TeX itself, so using this information assumes that you know a bit about \TeX 's internals. The other numbers and names are used consistently but are not frozen. So, when you use them for comparing you can best query a known primitive or character first to see the values.

You can ask for a list of commands:

```
local t = token.commands()
```

The id of a token class can be queried as follows:

```
local id = token.command_id("math_shift")
```

If you really know what you're doing you can create character tokens by not passing a string but a number:

```
local letter_x = token.create(string.byte("x"))
local other_x = token.create(string.byte("x"), 12)
```

Passing weird numbers can give side effects so don't expect too much help with that. As said, you need to know what you're doing. The best way to explore the way these internals work is to just look at how primitives or macros or `\chardef`'d commands are tokenized. Just create a known one and inspect its fields. A variant that ignores the current catcode table is:

```
local whatever = token.new(123, 12)
```

You can test if a control sequence is defined with `is_defined`, which accepts a string and returns a boolean:

```
local okay = token.is_defined("foo")
```

When a second argument to `is_defined` is `true` the check is for an undefined control sequence (only), otherwise any undefined command gives true.

The largest character possible is returned by `biggest_char`, just in case you need to know that boundary condition.

10.6.4 Macros

The `set_macro` function can get upto 4 arguments:

```
set_macro("csname", "content")
set_macro("csname", "content", "global")
set_macro("csname")
```

You can pass a catcodetable identifier as first argument:

```
set_macro(catcodetable, "csname", "content")
set_macro(catcodetable, "csname", "content", "global")
set_macro(catcodetable, "csname")
```



The results are like:

```
\def\csname{content}
\gdef\csname{content}
\def\csname{}
```

The `get_macro` function can be used to get the content of a macro while the `get_meaning` function gives the meaning including the argument specification (as usual in \TeX separated by `->`).

The `set_char` function can be used to do a `\chardef` at the Lua end, where invalid assignments are silently ignored:

```
set_char("csname", number)
set_char("csname", number, "global")
```

A special one is the following:

```
set_lua("mycode", id)
set_lua("mycode", id, "global", "protected")
```

This creates a token that refers to a Lua function with an entry in the table that you can access with `lua.get_functions_table`. It is the companion to `\luadef`.

10.6.5 Pushing back

There is a (for now) experimental putter:

```
local t1 = token.get_next()
local t2 = token.get_next()
local t3 = token.get_next()
local t4 = token.get_next()
-- watch out, we flush in sequence
token.put_next { t1, t2 }
-- but this one gets pushed in front
token.put_next ( t3, t4 )
```

When we scan `wxyz!` we get `yzwx!` back. The argument is either a table with tokens or a list of tokens. The new function `token.unchecked_put_next` has been added per request of the \LaTeX team. It skips this error checking and follows a different code path. It assumes that a valid token user datum is passed and can crash the engine otherwise.

The `token.expand` function will trigger expansion but what happens really depends on what you're doing where.

10.6.6 Nota bene

When scanning for the next token you need to keep in mind that we're not scanning like \TeX does: expanding, changing modes and doing things as it goes. When we scan with Lua we just pick up tokens. Say that we have:



`\bar`

but `\bar` is undefined. Normally T_EX will then issue an error message. However, when we have:

```
\def\foo{\bar}
```

We get no error, unless we expand `\foo` while `\bar` is still undefined. What happens is that as soon as T_EX sees an undefined macro it will create a hash entry and when later it gets defined that entry will be reused. So, `\bar` really exists but can be in an undefined state.

```
bar : bar
foo : foo
myfirstbar :
```

This was entered as:

```
bar      : \directlua{tex.print(token.scan_csname())}\bar
foo      : \directlua{tex.print(token.scan_csname())}\foo
myfirstbar : \directlua{tex.print(token.scan_csname())}\myfirstbar
```

The reason that you see `bar` reported and not `myfirstbar` is that `\bar` was already used in a previous paragraph.

If we now say:

```
\def\foo{}
```

we get:

```
bar : bar
foo : foo
myfirstbar :
```

And if we say

```
\def\foo{\bar}
```

we get:

```
bar : bar
foo : foo
myfirstbar :
```

When scanning from Lua we are not in a mode that defines (undefined) macros at all. There we just get the real primitive undefined macro token.

```
736235 536941998
731000 536941998
733121 536941998
```

This was generated with:



```

\directlua{local t = token.get_next() tex.print(t.id.." "..t.tok)}\myfirstbar
\directlua{local t = token.get_next() tex.print(t.id.." "..t.tok)}\mysecondbar
\directlua{local t = token.get_next() tex.print(t.id.." "..t.tok)}\mythirdbar

```

So, we do get a unique token because after all we need some kind of Lua object that can be used and garbage collected, but it is basically the same one, representing an undefined control sequence.

10.7 The kpse library

This library provides two separate, but nearly identical interfaces to the kpathsea file search functionality: there is a ‘normal’ procedural interface that shares its kpathsea instance with Lua_{TeX} itself, and an object oriented interface that is completely on its own.

10.7.1 set_program_name and new

The way the library looks up variables is driven by the `texmf.cnf` file where the currently set program name acts as filter. You can check what file is used by with `default_texmf.cnf`.

Before the search library can be used at all, its database has to be initialized. There are three possibilities, two of which belong to the procedural interface.

First, when Lua_{TeX} is used to typeset documents, this initialization happens automatically and the kpathsea executable and program names are set to `luatex` (that is, unless explicitly prohibited by the user’s startup script. See section 4.1 for more details).

Second, in `TeXLua` mode, the initialization has to be done explicitly via the `kpse.set_program_name` function, which 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.

Third, if you prefer the object oriented interface, you have to call a different function. It has the same arguments, but it returns a userdata variable.

```

local kpathsea = kpse.new(<string> name)
local kpathsea = kpse.new(<string> name, <string> progname)

```

Apart from these two functions, the calling conventions of the interfaces are identical. Depending on the chosen interface, you either call `kpse.find_file` or `kpathsea:find_file`, with identical arguments and return values.

10.7.2 record_input_file and record_output_file

These two function can be used to register used files. Because callbacks can load files themselves you might need these helpers (if you use recording at all).



```
kpse.record_input_file(<string> name)
kpse.record_output_file(<string> name)
```

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

The default type is `tex`. Note: this is different from `kpsewhich`, which tries to deduce the file type itself from looking at the supplied extension.

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`.

If `--output-directory` is specified and the value is a relative pathname, the file is searched first here and if it fails it will be searched in the standard tree.

10.7.4 lookup

A more powerful (but slower) generic method for finding files is also available. It returns a string for each found file.

```
<string> f, ... = kpse.lookup(<string> filename, <table> options)
```

The options match commandline arguments from `kpsewhich`:



| KEY | TYPE | EXPLANATION |
|-----------|-----------------|--|
| debug | number | set debugging flags for this lookup |
| format | string | use specific file type (see list above) |
| dpi | number | use this resolution for this lookup; default 600 |
| path | string | search in the given path |
| all | boolean | output all matches, not just the first |
| mustexist | boolean | search the disk as well as ls-R if necessary |
| mktexpk | boolean | disable/enable mktexpk generation for this lookup |
| mktextex | boolean | disable/enable mktextex generation for this lookup |
| mktexmf | boolean | disable/enable mktexmf generation for this lookup |
| mktexfm | boolean | disable/enable mktexfm generation for this lookup |
| subdir | string or table | only output matches whose directory part ends with the given string(s) |

If `--output-directory` is specified and the value is a relative pathname, the file is searched first here and then in the standard tree.

10.7.5 `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)
```

10.7.6 `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.

10.7.7 `expand_path`

Like `kpsewhich`'s `-expand-path`:

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

10.7.8 `expand_var`

Like `kpsewhich`'s `-expand-var`:

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



10.7.9 expand_braces

Like kpsewhich's -expand-braces:

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

10.7.10 in_name_ok

Returns true if fname is acceptable to open for reading, otherwise false and write a message to standard error.

```
<boolean> r = kpse.in_name_ok(<string> fname)
```

10.7.11 in_name_ok_silent_extended

```
<boolean> r = kpse.in_name_ok_silent_extended(<string> fname)
```

Returns true if fname is acceptable to open for reading; the values of TEXMFVAR and TEXMFSYSVAR are also checked for absolute filenames. Returns false otherwise but it doesn't write a message to standard error.

10.7.12 out_name_ok

Returns true if fname is acceptable to open for writing.

```
<boolean> r = kpse.out_name_ok(<string> fname)
```

10.7.13 out_name_ok_silent_extended

```
<boolean> r = kpse.out_name_ok_silent_extended(<string> fname)
```

Returns true if fname is acceptable to open for writing; the values of TEXMFVAR and TEXMFSYSVAR are also checked for absolute filenames. Returns false otherwise but it doesn't write a message to standard error.

10.7.14 show_path

Like kpsewhich's -show-path:

```
<string> r = kpse.show_path(<string> ftype)
```

10.7.15 var_value

Like kpsewhich's -var-value:

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



10.7.16 version

Returns the kpathsea version string.

```
<string> r = kpse.version()
```

10.7.17 check_permission

Checks if the filename can be executed or not. Returns 1, filename or a safe cmd alternative if it can be executed, otherwise returns 0 and an error message.

```
<string> res, cmd = kpse.check_permission(<string> filename)
```



11 The graphic libraries

11.1 The `img` library

The `img` library can be used as an alternative to `\pdfximage` and `\pdfrefximage`, and the associated ‘satellite’ commands like `\pdfximagebbox`. Image objects can also be used within virtual fonts via the `image` command listed in section 6.3.

11.1.1 `new`

```
<image> var = img.new()  
<image> var = img.new(<table> image_spec)
```

This function creates a userdata object of type ‘image’. The `image_spec` argument is optional. If it is given, it must be a table, and that table must contain a `filename` key. A number of other keys can also be useful, these are explained below.

You can either say

```
a = img.new()
```

followed by

```
a.filename = "foo.png"
```

or you can put the file name (and some or all of the other keys) into a table directly, like so:

```
a = img.new({filename='foo.pdf', page=1})
```

The generated `<image>` userdata object allows access to a set of user-specified values as well as a set of values that are normally filled in and updated automatically by Lua_T_E_X itself. Some of those are derived from the actual image file, others are updated to reflect the pdf output status of the object.

There is one required user-specified field: the file name (`filename`). It can optionally be augmented by the requested image dimensions (`width`, `depth`, `height`), user-specified image attributes (`attr`), the requested pdf page identifier (`page`), the requested boundingbox (`pagebox`) for pdf inclusion, the requested color space object (`colorspace`).

The function `img.new` does not access the actual image file, it just creates the `<image>` userdata object and initializes some memory structures. The `<image>` object and its internal structures are automatically garbage collected.

Once the image is scanned, all the values in the `<image>` except `width`, `height` and `depth`, become frozen, and you cannot change them any more.

You can use `pdf.setignoreunknownimages(1)` (or at the _T_E_X end the `\pdfvariable ignoreunknownimages`) to get around a quit when no known image type is found (based on name or preamble). Beware: this will not catch invalid images and we cannot guarantee side effects.



A zero dimension image is still included when requested. No special flags are set. A proper workflow will not rely in such a catch but make sure that images are valid.

11.1.2 fields

```
<table> keys = img.fields()
```

This function returns a list of all the possible `image_spec` keys, both user-supplied and automatic ones.

| FIELD NAME | TYPE | DESCRIPTION |
|------------------------------|---------|---|
| <code>attr</code> | string | the image attributes for Lua _T _E _X |
| <code>bbox</code> | table | table with 4 boundingbox dimensions <code>llx</code> , <code>lly</code> , <code>urx</code> and <code>ury</code> overruling the <code>pagebox</code> entry |
| <code>colordepth</code> | number | the number of bits used by the color space |
| <code>colorspace</code> | number | the color space object number |
| <code>depth</code> | number | the image depth for Lua _T _E _X |
| <code>filename</code> | string | the image file name |
| <code>filepath</code> | string | the full (expanded) file name of the image |
| <code>height</code> | number | the image height for Lua _T _E _X |
| <code>imagetype</code> | string | one of <code>pdf</code> , <code>png</code> , <code>jpg</code> , <code>jp2</code> or <code>jbig2</code> |
| <code>index</code> | number | the pdf image name suffix |
| <code>objnum</code> | number | the pdf image object number |
| <code>page</code> | number | the identifier for the requested image page |
| <code>pagebox</code> | string | the requested bounding box, one of <code>none</code> , <code>media</code> , <code>crop</code> , <code>bleed</code> , <code>trim</code> , <code>art</code> |
| <code>pages</code> | number | the total number of available pages |
| <code>rotation</code> | number | the image rotation from included pdf file, in multiples of 90 deg. |
| <code>stream</code> | string | the raw stream data for an <code>/XObject</code> <code>/Form</code> object |
| <code>transform</code> | number | the image transform, integer number 0..7 |
| <code>orientation</code> | number | the (jpeg) image orientation, integer number 1..8 (0 for unset) |
| <code>width</code> | number | the image width for Lua _T _E _X |
| <code>xres</code> | number | the horizontal natural image resolution (in dpi) |
| <code>xsize</code> | number | the natural image width |
| <code>yres</code> | number | the vertical natural image resolution (in dpi) |
| <code>ysize</code> | number | the natural image height |
| <code>visiblefilename</code> | string | when set, this name will find its way in the pdf file as PTEX specification; when an empty string is assigned nothing is written to file; otherwise the natural filename is taken |
| <code>userpassword</code> | string | the userpassword needed for opening a pdf file |
| <code>ownerpassword</code> | string | the ownerpassword needed for opening a pdf file |
| <code>keepopen</code> | boolean | keep the pdf file open |
| <code>nobbox</code> | boolean | don't add a boundingbox specification for streams |
| <code>nolength</code> | boolean | don't add length key nor compress for streams |
| <code>nosize</code> | boolean | don't add size fields for streams |



A running (undefined) dimension in width, height, or depth is represented as `nil` in Lua, so if you want to load an image at its 'natural' size, you do not have to specify any of those three fields.

The `stream` parameter allows to fabricate an `/XObject /Form` object from a string giving the stream contents, e.g., for a filled rectangle:

```
a.stream = "0 0 20 10 re f"
```

When writing the image, an `/XObject /Form` object is created, like with embedded pdf file writing. The object is written out only once. The `stream` key requires that also the `bbox` table is given. The `stream` key conflicts with the `filename` key. The `transform` key works as usual also with `stream`.

The `bbox` key needs a table with four boundingbox values, e.g.:

```
a.bbox = { "30bp", 0, "225bp", "200bp" }
```

This replaces and overrules any given `pagebox` value; with given `bbox` the box dimensions coming with an embedded pdf file are ignored. The `xsize` and `ysize` dimensions are set accordingly, when the image is scaled. The `bbox` parameter is ignored for non-pdf images.

The `transform` allows to mirror and rotate the image in steps of 90 deg. The default value 0 gives an unmirrored, unrotated image. Values 1 – 3 give counterclockwise rotation by 90, 180, or 270 degrees, whereas with values 4 – 7 the image is first mirrored and then rotated counterclockwise by 90, 180, or 270 degrees. The `transform` operation gives the same visual result as if you would externally preprocess the image by a graphics tool and then use it by `LuaTeX`. If a pdf file to be embedded already contains a `/Rotate` specification, the rotation result is the combination of the `/Rotate` rotation followed by the `transform` operation.

11.1.3 scan

```
<image> var = img.scan(<image> var)
<image> var = img.scan(<table> image_spec)
```

When you say `img.scan(a)` for a new image, the file is scanned, and variables such as `xsize`, `ysize`, image type, number of pages, and the resolution are extracted. Each of the width, height, depth fields are set up according to the image dimensions, if they were not given an explicit value already. An image file will never be scanned more than once for a given image variable. With all subsequent `img.scan(a)` calls only the dimensions are again set up (if they have been changed by the user in the meantime).

For ease of use, you can do right-away a

```
<image> a = img.scan { filename = "foo.png" }
```

without a prior `img.new`.

Nothing is written yet at this point, so you can do `a=img.scan`, retrieve the available info like image width and height, and then throw away `a` again by saying `a=nil`. In that case no image object will be reserved in the PDF, and the used memory will be cleaned up automatically.



11.1.4 copy

```
<image> var = img.copy(<image> var)
<image> var = img.copy(<table> image_spec)
```

If you say `a = b`, then both variables point to the same `<image>` object. if you want to write out an image with different sizes, you can do `b = img.copy(a)`.

Afterwards, `a` and `b` still reference the same actual image dictionary, but the dimensions for `b` can now be changed from their initial values that were just copies from `a`.

11.1.5 write, immediatewrite, immediatewriteobject

```
<image> var = img.write(<image> var)
<image> var = img.write(<table> image_spec)
```

By `img.write(a)` a pdf object number is allocated, and a rule node of subtype `image` is generated and put into the output list. By this the image `a` is placed into the page stream, and the image file is written out into an image stream object after the shipping of the current page is finished.

Again you can do a terse call like

```
img.write { filename = "foo.png" }
```

The `<image>` variable is returned in case you want it for later processing. You can also write an object.

By `img.immediatewrite(a)` a pdf object number is allocated, and the image file for image `a` is written out immediately into the pdf file as an image stream object (like with `\immediate\pdfx-image`). The object number of the image stream dictionary is then available by the `objnum` key. No `pdf_refximage` whatsit node is generated. You will need an `img.write(a)` or `img.node(a)` call to let the image appear on the page, or reference it by another trick; else you will have a dangling image object in the pdf file.

```
<image> var = img.immediatewrite(<image> var)
<image> var = img.immediatewrite(<table> image_spec)
```

Also here you can do a terse call like

```
a = img.immediatewrite { filename = "foo.png" }
```

The `<image>` variable is returned and you will most likely need it.

The next function is kind of special as it copies an object from a (pdf) image file. This features is experimental and might disappear.

```
<integer> objnum = img.immediatewriteobject(<image> var, <integer> objnum)
<integer> objnum = img.immediatewriteobject(<table> image_spec, <integer> objnum)
```



11.1.6 node

```
<node> n = img.node(<image> var)
<node> n = img.node(<table> image_spec)
```

This function allocates a pdf object number and returns a whatsit node of subtype pdf_refximage, filled with the image parameters width, height, depth, and objnum. Also here you can do a terse call like:

```
n = img.node ({ filename = "foo.png" })
```

This example outputs an image:

```
node.write(img.node{filename="foo.png"})
```

11.1.7 types

```
<table> types = img.types()
```

This function returns a list with the supported image file type names, currently these are pdf, png, jpg, jp2 (JPEG 2000), and jbig2.

11.1.8 boxes

```
<table> boxes = img.boxes()
```

This function returns a list with the supported pdf page box names, currently these are media, crop, bleed, trim, and art, all in lowercase.

The pdf file is kept open after its properties are determined. After inclusion, which happens when the page that references the image is flushed, the file is closed. This means that when you have thousands of images on one page, your operating system might decide to abort the run. When you include more than one page from a pdf file you can set the keepopen flag when you allocate an image object, or pass the keepopen directive when you refer to the image with `\useimageresource`. This only makes sense when you embed many pages. An `\immediate` applied to `\saveimageresource` will also force a close after inclusion.

```
\immediate\useimageresource{foo.pdf}%
    \saveimageresource          \lastsavedimageresourceindex % closed
    \useimageresource{foo.pdf}%
    \saveimageresource          \lastsavedimageresourceindex % kept open
    \useimageresource{foo.pdf}%
    \saveimageresource keepopen\lastsavedimageresourceindex % kept open

\directlua{img.write(img.scan{ file = "foo.pdf" })} % closed
\directlua{img.write(img.scan{ file = "foo.pdf", keepopen = true })} % kept open
```



11.2 The mplib library

The MetaPost library interface registers itself in the table `mplib`. It is based on `mplib` version 2.11.

11.2.1 new

To create a new MetaPost instance, call

```
<mpinstance> mp = mplib.new({...})
```

This creates the `mp` instance object. The argument hash can have a number of different fields, as follows:

| NAME | TYPE | DESCRIPTION | DEFAULT |
|--------------------------|----------|--|------------------|
| <code>error_line</code> | number | error line width | 79 |
| <code>print_line</code> | number | line length in ps output | 100 |
| <code>random_seed</code> | number | the initial random seed | variable |
| <code>math_mode</code> | string | the number system to use: scaled, double or decimal | scaled |
| <code>interaction</code> | string | the interaction mode: batch, nonstop, scroll or errorstop | errorstop |
| <code>job_name</code> | string | --jobname | mpout |
| <code>find_file</code> | function | a function to find files | only local files |

The binary mode is no longer available in the LuaTeX version of `mplib`. It offers no real advantage and brings a ton of extra libraries with platform specific properties that we can now avoid. We might introduce a high resolution scaled variant at some point but only when it pays of performance wise.

The `find_file` function should be of this form:

```
<string> found = finder (<string> name, <string> mode, <string> type)
```

with:

| NAME | THE REQUESTED FILE |
|-------------------|--|
| <code>mode</code> | the file mode: r or w |
| <code>type</code> | the kind of file, one of: mp, tfm, map, pfb, enc |

Return either the full path name of the found file, or `nil` if the file cannot be found.

Note that the new version of `mplib` no longer uses binary mem files, so the way to preload a set of macros is simply to start off with an `input` command in the first `execute` call.

When you are processing a snippet of text starting with `btex` and ending with either `etex` or `verbatimtex`, the MetaPost `texscriptmode` parameter controls how spaces and newlines get honoured. The default value is 1. Possible values are:

| NAME | MEANING |
|------|-------------|
| 0 | no newlines |



- 1 newlines in verbatim`tex`
 - 2 newlines in verbatim`tex` and `etex`
 - 3 no leading and trailing strip in verbatim`tex`
 - 4 no leading and trailing strip in verbatim`tex` and `btex`
-

That way the Lua handler (assigned to `make_text`) can do what it likes. An `etex` has to be followed by a space or `;` or be at the end of a line and preceded by a space or at the beginning of a line.

11.2.2 statistics

You can request statistics with:

```
<table> stats = mp:statistics()
```

This function returns the vital statistics for an `mplib` instance. There are four fields, giving the maximum number of used items in each of four allocated object classes:

| FIELD | TYPE | EXPLANATION |
|--------------------------|--------|-------------------------------|
| <code>main_memory</code> | number | memory size |
| <code>hash_size</code> | number | hash size |
| <code>param_size</code> | number | simultaneous macro parameters |
| <code>max_in_open</code> | number | input file nesting levels |

Note that in the new version of `mplib`, this is informational only. The objects are all allocated dynamically, so there is no chance of running out of space unless the available system memory is exhausted.

11.2.3 execute

You can ask the MetaPost interpreter to run a chunk of code by calling

```
<table> rettable = execute(mp,"metapost code")
```

for various bits of MetaPost language input. Be sure to check the `rettable.status` (see below) because when a fatal MetaPost error occurs the `mplib` instance will become unusable thereafter.

Generally speaking, it is best to keep your chunks small, but beware that all chunks have to obey proper syntax, like each of them is a small file. For instance, you cannot split a single statement over multiple chunks.

In contrast with the normal stand alone `mpost` command, there is *no* implied ‘input’ at the start of the first chunk.

11.2.4 finish

```
<table> rettable = finish(mp)
```



If for some reason you want to stop using an `mplib` instance while processing is not yet actually done, you can call `finish`. Eventually, used memory will be freed and open files will be closed by the Lua garbage collector, but an explicit `finish` is the only way to capture the final part of the output streams.

11.2.5 Result table

The return value of `execute` and `finish` is a table with a few possible keys (only `status` is always guaranteed to be present).

| FIELD | TYPE | EXPLANATION |
|---------------------|--------|--|
| <code>log</code> | string | output to the 'log' stream |
| <code>term</code> | string | output to the 'term' stream |
| <code>error</code> | string | output to the 'error' stream (only used for 'out of memory') |
| <code>status</code> | number | the return value: 0 = good, 1 = warning, 2 = errors, 3 = fatal error |
| <code>fig</code> | table | an array of generated figures (if any) |

When `status` equals 3, you should stop using this `mplib` instance immediately, it is no longer capable of processing input.

If it is present, each of the entries in the `fig` array is a userdata representing a figure object, and each of those has a number of object methods you can call:

| FIELD | TYPE | EXPLANATION |
|---------------------------|----------|---|
| <code>boundingbox</code> | function | returns the bounding box, as an array of 4 values |
| <code>postscript</code> | function | returns a string that is the ps output of the <code>fig</code> . this function accepts two optional integer arguments for specifying the values of <code>prologues</code> (first argument) and <code>procset</code> (second argument) |
| <code>svg</code> | function | returns a string that is the svg output of the <code>fig</code> . This function accepts an optional integer argument for specifying the value of <code>prologues</code> |
| <code>objects</code> | function | returns the actual array of graphic objects in this <code>fig</code> |
| <code>copy_objects</code> | function | returns a deep copy of the array of graphic objects in this <code>fig</code> |
| <code>filename</code> | function | the filename this <code>fig</code> 's PostScript output would have written to in stand alone mode |
| <code>width</code> | function | the <code>fontcharwd</code> value |
| <code>height</code> | function | the <code>fontcharht</code> value |
| <code>depth</code> | function | the <code>fontchardp</code> value |
| <code>italcorr</code> | function | the <code>fontcharit</code> value |
| <code>charcode</code> | function | the (rounded) <code>charcode</code> value |

Note: you can call `fig:objects()` only once for any one `fig` object!

When the `boundingbox` represents a 'negated rectangle', i.e. when the first set of coordinates is larger than the second set, the picture is empty.

Graphical objects come in various types that each has a different list of accessible values. The types are: `fill`, `outline`, `text`, `start_clip`, `stop_clip`, `start_bounds`, `stop_bounds`, `special`.

There is a helper function (`mplib.fields(obj)`) to get the list of accessible values for a particular object, but you can just as easily use the tables given below.



All graphical objects have a field type that gives the object type as a string value; it is not explicit mentioned in the following tables. In the following, numbers are PostScript points represented as a floating point number, unless stated otherwise. Field values that are of type table are explained in the next section.

11.2.5.1 fill

| FIELD | TYPE | EXPLANATION |
|------------|--------|---|
| path | table | the list of knots |
| htap | table | the list of knots for the reversed trajectory |
| pen | table | knots of the pen |
| color | table | the object's color |
| linejoin | number | line join style (bare number) |
| miterlimit | number | miterlimit |
| prescript | string | the prescript text |
| postscript | string | the postscript text |

The entries htap and pen are optional.

11.2.5.2 outline

| FIELD | TYPE | EXPLANATION |
|------------|--------|-------------------------------|
| path | table | the list of knots |
| pen | table | knots of the pen |
| color | table | the object's color |
| linejoin | number | line join style (bare number) |
| miterlimit | number | miterlimit |
| linecap | number | line cap style (bare number) |
| dash | table | representation of a dash list |
| prescript | string | the prescript text |
| postscript | string | the postscript text |

The entry dash is optional.

11.2.5.3 text

| FIELD | TYPE | EXPLANATION |
|-----------|--------|-----------------------|
| text | string | the text |
| font | string | font tfm name |
| dsize | number | font size |
| color | table | the object's color |
| width | number | |
| height | number | |
| depth | number | |
| transform | table | a text transformation |



| | | |
|------------|--------|---------------------|
| prescript | string | the prescript text |
| postscript | string | the postscript text |

11.2.5.4 special

| FIELD | TYPE | EXPLANATION |
|-----------|--------|--------------|
| prescript | string | special text |

11.2.5.5 start_bounds, start_clip

| FIELD | TYPE | EXPLANATION |
|-------|-------|-------------------|
| path | table | the list of knots |

11.2.5.6 stop_bounds, stop_clip

Here are no fields available.

11.2.6 Subsidiary table formats

11.2.6.1 Paths and pens

Paths and pens (that are really just a special type of paths as far as mplib is concerned) are represented by an array where each entry is a table that represents a knot.

| FIELD | TYPE | EXPLANATION |
|------------|--------|--|
| left_type | string | when present: endpoint, but usually absent |
| right_type | string | like left_type |
| x_coord | number | X coordinate of this knot |
| y_coord | number | Y coordinate of this knot |
| left_x | number | X coordinate of the precontrol point of this knot |
| left_y | number | Y coordinate of the precontrol point of this knot |
| right_x | number | X coordinate of the postcontrol point of this knot |
| right_y | number | Y coordinate of the postcontrol point of this knot |

There is one special case: pens that are (possibly transformed) ellipses have an extra stringB A valued key type with value `elliptical` besides the array part containing the knot list.

11.2.6.2 Colors

A color is an integer array with 0, 1, 3 or 4 values:

| FIELD | TYPE | EXPLANATION |
|-------|--------------|---|
| 0 | marking only | no values |
| 1 | greyscale | one value in the range (0, 1), 'black' is 0 |



| | | |
|---|------|--|
| 3 | rgb | three values in the range (0, 1), 'black' is 0, 0, 0 |
| 4 | cmyk | four values in the range (0, 1), 'black' is 0, 0, 0, 1 |

If the color model of the internal object was uninitialized, then it was initialized to the values representing 'black' in the colorspace `defaultcolormodel` that was in effect at the time of the shipout.

11.2.6.3 Transforms

Each transform is a six-item array.

| INDEX | TYPE | EXPLANATION |
|-------|--------|---------------|
| 1 | number | represents x |
| 2 | number | represents y |
| 3 | number | represents xx |
| 4 | number | represents yx |
| 5 | number | represents xy |
| 6 | number | represents yy |

Note that the translation (index 1 and 2) comes first. This differs from the ordering in PostScript, where the translation comes last.

11.2.6.4 Dashes

Each dash is two-item hash, using the same model as PostScript for the representation of the dashlist. `dashes` is an array of 'on' and 'off', values, and `offset` is the phase of the pattern.

| FIELD | TYPE | EXPLANATION |
|---------------------|--------|----------------------------|
| <code>dashes</code> | hash | an array of on-off numbers |
| <code>offset</code> | number | the starting offset value |

11.2.7 Pens and `pen_info`

There is helper function (`pen_info(obj)`) that returns a table containing a bunch of vital characteristics of the used pen (all values are floats):

| FIELD | TYPE | EXPLANATION |
|--------------------|--------|------------------|
| <code>width</code> | number | width of the pen |
| <code>sx</code> | number | x scale |
| <code>rx</code> | number | xy multiplier |
| <code>ry</code> | number | yx multiplier |
| <code>sy</code> | number | y scale |
| <code>tx</code> | number | x offset |
| <code>ty</code> | number | y offset |



11.2.8 Character size information

These functions find the size of a glyph in a defined font. The fontname is the same name as the argument to `infont`; the char is a glyph id in the range 0 to 255; the returned `w` is in AFM units.

11.2.8.1 `char_width`

```
<number> w = char_width(mp,<string> fontname, <number> char)
```

11.2.8.2 `char_height`

```
<number> w = char_height(mp,<string> fontname, <number> char)
```

11.2.8.3 `char_depth`

```
<number> w = char_depth(mp,<string> fontname, <number> char)
```

11.2.8.4 `get_[boolean|numeric|string|path]`

When a script call brings you from the MetaPost run (temporarily) back to Lua you can access variables, but only if they are known (so for instance anonymous capsules like loop variables are not accessible).

```
<boolean> w = get_boolean(mp,<string> name)
<number> n = get_numeric(mp,<string> name)
<string> s = get_string (mp,<string> name)
<table> p = get_path (mp,<string> name)
```

The path is returned as a table with subtables that have six numbers: the coordinates of the point, pre- and postcontrol. A `cycle` field indicates if a path is cyclic.



12 The fontloader

The fontloader library is sort of independent of the rest in the sense that it can load font into a Lua table that then can be converted into a table suitable for T_EX. The library is an adapted subset of FontForge and as such gives a similar view on a font (which has advantages when you want to debug). We will not discuss OpenType in detail here as the Microsoft website offers enough information about it. The tables returned by the loader are not that far from the standard. We have no plans to extend the loader (it may even become an external module at some time).

12.1 Getting quick information on a font

When you want to locate font by name you need some basic information that is hidden in the font files. For that reason we provide an efficient helper that gets the basic information without loading all of the font. Normally this helper is used to create a font (name) database.

```
<table> info =  
    fontloader.info(<string> 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 some 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 |
| units_per_em | number | 1000 for PostScript-based fonts, usually 2048 for TrueType |
| pfminfo | table | (see section 12.6.6) |

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.

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 fontloader library, the simplest way to get that information is thus:

```
function load_font (filename)  
    local metrics = nil  
    local font = fontloader.open(filename)  
    if font then
```



```

    metrics = fontloader.to_table(font)
    fontloader.close(font)
end
return metrics
end

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

```

The main function call is

```

<userdata> f, <table> w = fontloader.open(<string> filename)
<userdata> f, <table> w = fontloader.open(<string> filename, <string> fontname)

```

The first return value is a userdata representation of the font. The second return value is a table containing any warnings and errors reported by fontloader 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') and dfont collections, you have to use a second string argument to specify which font you want from the collection. Use the fontname strings that are returned by fontloader.info for that.

To turn the font into a table, fontloader.to_table is used on the font returned by fontloader.open.

```

<table> f = fontloader.to_table(<userdata> font)

```

This table cannot be used directly by Lua_T_E_X and should be turned into another one as described in chapter 6. Do not forget to store the fontname value in the psname field of the metrics table to be returned to Lua_T_E_X, otherwise the font inclusion backend will not be able to find the correct font in the collection.

See section 12.5 for details on the userdata object returned by fontloader.open and the layout of the metrics table returned by fontloader.to_table.

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.

A loaded font is discarded with:

```

fontloader.close(<userdata> font)

```



12.3 Applying a ‘feature file’

You can apply a ‘feature file’ to a loaded font:

```
<table> errors = fontloader.apply_featurefile(<userdata> font, <string> 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.

If the function fails, the return value is a table containing any errors reported by fontloader while applying the feature file. On success, nil is returned.

12.4 Applying an ‘AFM file’

You can apply an ‘afm file’ to a loaded font:

```
<table> errors = fontloader.apply_afmfile(<userdata> font, <string> filename)
```

An afm file is a textual representation of (some of) the meta information in a Type1 font. See

ftp://ftp.math.utah.edu/u/ma/hohn/linux/postscript/5004.AFM_Spec.pdf

for more information about afm files.

Note: If you fontloader.open a Type1 file named font.pfb, the library will automatically search for and apply font.afm if it exists in the same directory as the file font.pfb. In that case, there is no need for an explicit call to apply_afmfile().

If the function fails, the return value is a table containing any errors reported by fontloader while applying the AFM file. On success, nil is returned.

12.5 Fontloader font tables

As mentioned earlier, the return value of fontloader.open is a userdata object. One way to have access to the actual metrics is to call fontloader.to_table on this object, returning the table structure that is explained in the following sections. In the following sections we will not explain each field in detail. Most fields are self descriptive and for the more technical aspects you need to consult the relevant font references.

It turns out that the result from fontloader.to_table sometimes needs very large amounts of memory (depending on the font’s complexity and size) so it is possible to access the userdata object directly.



- ▶ All top-level keys that would be returned by `to_table()` can also be accessed directly.
- ▶ The top-level key 'glyphs' returns a *virtual* array that allows indices from `f.glyphmin` to `(f.glyphmax)`.
- ▶ The items in that virtual array (the actual glyphs) are themselves also userdata objects, and each has accessors for all of the keys explained in the section 'Glyph items' below.
- ▶ The top-level key 'subfonts' returns an *actual* array of userdata objects, one for each of the subfonts (or nil, if there are no subfonts).

A short example may be helpful. This code generates a printout of all the glyph names in the font `PunkNova.kern.otf`:

```
local f = fontloader.open('PunkNova.kern.otf')
print (f.fontname)
local i = 0
if f.glyphcnt > 0 then
  for i=f.glyphmin,f.glyphmax do
    local g = f.glyphs[i]
    if g then
      print(g.name)
    end
    i = i + 1
  end
end
fontloader.close(f)
```

In this case, the LuaTeX memory requirement stays below 100MB on the test computer, while the internal structure generated by `to_table()` needs more than 2GB of memory (the font itself is 6.9MB in disk size).

Only the top-level font, the subfont table entries, and the glyphs are virtual objects, everything else still produces normal Lua values and tables.

If you want to know the valid fields in a font or glyph structure, call the `fields` function on an object of a particular type (either glyph or font):

```
<table> fields = fontloader.fields(<userdata> font)
<table> fields = fontloader.fields(<userdata> font_glyph)
```

For instance:

```
local fields = fontloader.fields(f)
local fields = fontloader.fields(f.glyphs[0])
```

12.6 Table types

12.6.1 The main table

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



| KEY | TYPE | explanation |
|------------------------------|--------|--|
| table_version | string | indicates the metrics version (currently 0.3) |
| fontname | string | PostScript font name |
| fullname | string | official (human-oriented) 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 | |
| uniqueid | number | |
| glyphs | array | |
| glyphcnt | number | number of included glyphs |
| glyphmax | number | maximum used index the glyphs array |
| glyphmin | number | minimum used index the glyphs array |
| notdef_loc | number | location of the .notdef glyph or -1 when not present |
| hasvmetrics | number | |
| onlybitmaps | number | |
| serifcheck | number | |
| issarif | number | |
| issans | number | |
| encodingchanged | number | |
| strokedfont | number | |
| use_typo_metrics | 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 | |
| comments | string | |
| fontlog | string | |
| cvt_names | string | |
| anchor_classes | table | |



| | |
|------------------|---------------------------------|
| ttf_tables | table |
| ttf_tab_saved | table |
| kerns | table |
| vkerns | table |
| texdata | table |
| lookups | table |
| gpos | table |
| gsub | table |
| mm | table |
| chosename | string |
| macstyle | number |
| fondname | string |
| fontstyle_id | number |
| fontstyle_name | table |
| strokewidth | float |
| mark_classes | table |
| creationtime | number |
| modificationtime | number |
| os2_version | number |
| math | table |
| validation_state | table |
| horiz_base | table |
| vert_base | table |
| extrema_bound | number |
| truetype | boolean signals a TrueType font |

12.6.2 glyphs

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

| KEY | TYPE | EXPLANATION |
|--------------|--------|---|
| name | string | the glyph name |
| unicode | number | unicode code point, or -1 |
| boundingbox | array | array of four numbers, see note below |
| width | number | only for horizontal fonts |
| vwidth | number | only for vertical fonts |
| tsidebearing | number | only for vertical ttf/otf fonts, and only if non-zero |
| lsidebearing | number | only if non-zero and not equal to boundingbox[1] |
| class | string | one of "none", "base", "ligature", "mark", "component" (if not present, the glyph class is 'automatic') |
| 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 |
| comment | string | only if set |
| tex_height | number | only if set |
| tex_depth | number | only if set |
| italic_correction | number | only if set |
| top_accent | number | only if set |
| is_extended_shape | number | only if this character is part of a math extension list |
| altuni | table | alternate Unicode items |
| vert_variants | table | |
| horiz_variants | table | |
| mathkern | table | |

On boundingbox: The boundingbox information for TrueType fonts and TrueType-based otf fonts is read directly from the font file. PostScript-based fonts do not have this information, so the boundingbox of traditional PostScript fonts is generated by interpreting the actual bezier curves to find the exact boundingbox. This can be a slow process, so the boundingboxes of PostScript-based otf fonts (and raw cff fonts) are calculated using an approximation of the glyph shape based on the actual glyph points only, instead of taking the whole curve into account. This means that glyphs that have missing points at extrema will have a too-tight boundingbox, but the processing is so much faster that in our opinion the tradeoff is worth it.

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, chain-sub, 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 item in the <code>lookups</code> table explained above |
| 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 a 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 |
|---------------------------|--------|-------------------------------------|
| <code>x</code> | number | <code>x</code> location |
| <code>y</code> | number | <code>y</code> location |
| <code>ttf_pt_index</code> | number | truetype point index, only if given |

For `baselig`, the value is a small array of such anchor 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 } }
  }
}
```



```
    }
}
```

Note: The baselig table can be sparse!

12.6.3 map

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

| KEY | TYPE | EXPLANATION |
|---------|--------|---------------------------------------|
| encount | 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 non-zero |
| is_unicodedefull | number | only if non-zero |
| is_custom | number | only if non-zero |
| is_original | number | only if non-zero |
| is_compact | number | only if non-zero |
| is_japanese | number | only if non-zero |
| is_korean | number | only if non-zero |
| is_tradchinese | number | only if non-zero [name?] |
| is_simplechinese | number | only if non-zero |



| | |
|-----------------|--------|
| low_page | number |
| high_page | number |
| iconv_name | string |
| iso_2022_escape | string |

12.6.4 private

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

12.6.5 cidinfo

| KEY | TYPE | EXPLANATION |
|------------|--------|-------------|
| registry | string | |
| ordering | string | |
| supplement | number | |
| version | number | |

12.6.6 pfminfo

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 | |
| 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 | |
| codepages | table | A two-number array of encoded code pages |
| unicoderanges | table | A four-number array of encoded unicode ranges |
| 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 | idem |
| proportion | string | idem |
| contrast | string | idem |
| strokevariation | string | idem |
| armstyle | string | idem |
| letterform | string | idem |
| midline | string | idem |
| xheight | string | idem |

12.6.7 names

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: copyright, family, subfamily, uniqueid, fullname, version, postscriptname, trademark, manufacturer, designer, descriptor, venderurl, designerurl, license, licenseurl, idontknow, preffamilyname, premodifiers, compatfull, sampletex, cidfindfontname, wwsfamily and wwssubfamily.

12.6.8 anchor_classes

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 |

12.6.9 gpos

The gpos table has one array entry for each lookup. (The gpos_ prefix is somewhat redundant.)

| 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 | |
| ignorerecombiningmarks | boolean | |
| mark_class | string | |

The features subtable items of gpos have:

| KEY | TYPE | EXPLANATION |
|---------|--------|-------------|
| tag | string | |
| scripts | table | |

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 or array | associated lookup(s) |
| offsets | array of numbers | |

Note: the kernclass (as far as we can see) always has one entry so it could be one level deep instead. Also the seconds start at [2] which is close to the fontforge internals so we keep that too.

12.6.10 gsub

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 |

12.6.11 ttf_tables and ttf_tab_saved

| KEY | TYPE | EXPLANATION |
|--------|--------|-------------|
| tag | string | |
| len | number | |
| maxlen | number | |
| data | number | |

12.6.12 mm

| KEY | TYPE | EXPLANATION |
|------|-------|---------------------|
| axes | table | array of axis names |



| | | |
|----------------|--------|--|
| instance_count | number | |
| positions | table | array of instance positions (#axes * instances) |
| defweights | table | array of default weights for instances |
| cdv | string | |
| ndv | string | |
| axismaps | table | |

The axismaps:

| KEY | TYPE | EXPLANATION |
|---------|--------|---------------------------|
| blends | table | an array of blend points |
| designs | table | an array of design values |
| min | number | |
| def | number | |
| max | number | |

12.6.13 mark_classes

The keys in this table are mark class names, and the values are a space-separated string of glyph names in this class.

12.6.14 math

The math table has the variables that are also discussed in the chapter about math: ScriptPercentScaleDown, ScriptScriptPercentScaleDown, DelimitedSubFormulaMinHeight, DisplayOperatorMinHeight, MathLeading, AxisHeight, AccentBaseHeight, FlattenedAccentBaseHeight, SubscriptShiftDown, SubscriptTopMax, SubscriptBaselineDropMin, SuperscriptShiftUp, SuperscriptShiftUpCramped, SuperscriptBottomMin, SuperscriptBaselineDropMax, SubSuperscriptGapMin, SuperscriptBottomMaxWithSubscript, SpaceAfterScript, UpperLimitGapMin, UpperLimitBaselineRiseMin, LowerLimitGapMin, LowerLimitBaselineDropMin, StackTopShiftUp, StackTopDisplayStyleShiftUp, StackBottomShiftDown, StackBottomDisplayStyleShiftDown, StackGapMin, StackDisplayStyleGapMin, StretchStackTopShiftUp, StretchStackBottomShiftDown, StretchStackGapAboveMin, StretchStackGapBelowMin, FractionNumeratorShiftUp, FractionNumeratorDisplayStyleShiftUp, FractionDenominatorShiftDown, FractionDenominatorDisplayStyleShiftDown, FractionNumeratorGapMin, FractionNumeratorDisplayStyleGapMin, FractionRuleThickness, FractionDenominatorGapMin, FractionDenominatorDisplayStyleGapMin, SkewedFractionHorizontalGap, SkewedFractionVerticalGap, OverbarVerticalGap, OverbarRuleThickness, OverbarExtraAscender, UnderbarVerticalGap, UnderbarRuleThickness, UnderbarExtraDescender, RadicalVerticalGap, RadicalDisplayStyleVerticalGap, RadicalRuleThickness, RadicalExtraAscender, RadicalKernBeforeDegree, RadicalKernAfterDegree, RadicalDegreeBottomRaisePercent, MinConnectorOverlap, FractionDelimiterSize and FractionDelimiterDisplayStyleSize.



12.6.15 validation_state

This is just a bonus table with keys: `bad_ps_fontname`, `bad_glyph_table`, `bad_cff_table`, `bad_metrics_table`, `bad_cmap_table`, `bad_bitmaps_table`, `bad_gx_table`, `bad_ot_table`, `bad_os2_version` and `bad_sfnt_header`.

12.6.16 horiz_base and vert_base

| KEY | TYPE | EXPLANATION |
|----------------------|-------|------------------------------|
| <code>tags</code> | table | an array of script list tags |
| <code>scripts</code> | table | |

The `scripts` subtable:

| KEY | TYPE | EXPLANATION |
|-------------------------------|--------|-------------|
| <code>baseline</code> | table | |
| <code>default_baseline</code> | number | |
| <code>lang</code> | table | |

The `lang` subtable:

| KEY | TYPE | EXPLANATION |
|-----------------------|--------|--------------|
| <code>tag</code> | string | a script tag |
| <code>ascent</code> | number | |
| <code>descent</code> | number | |
| <code>features</code> | table | |

The `features` points to an array of tables with the same layout except that in those nested tables, the tag represents a language.

12.6.17 altuni

An array of alternate Unicode values. Inside that array are hashes with:

| KEY | TYPE | EXPLANATION |
|----------------------|--------|--|
| <code>unicode</code> | number | this glyph is also used for this unicode |
| <code>variant</code> | number | the alternative is driven by this unicode selector |

12.6.18 vert_variants and horiz_variants

| KEY | TYPE | EXPLANATION |
|--------------------------------|--------|-------------|
| <code>variants</code> | string | |
| <code>italic_correction</code> | number | |
| <code>parts</code> | table | |

The `parts` table is an array of smaller tables:



| KEY | TYPE | EXPLANATION |
|-----------|--------|-------------|
| component | string | |
| extender | number | |
| start | number | |
| end | number | |
| advance | number | |

12.6.19 mathkern

| KEY | TYPE | EXPLANATION |
|--------------|-------|-------------|
| top_right | table | |
| bottom_right | table | |
| top_left | table | |
| bottom_left | table | |

Each of the subtables is an array of small hashes with two keys:

| KEY | TYPE | EXPLANATION |
|--------|--------|-------------|
| height | number | |
| kern | number | |

12.6.20 kerns

Substructure is identical to the per-glyph subtable.

12.6.21 vkerns

Substructure is identical to the per-glyph subtable.

12.6.22 texdata

| KEY | TYPE | EXPLANATION |
|--------|--------|----------------------------|
| type | string | unset, text, math, mathext |
| params | array | 22 font numeric parameters |

12.6.23 lookups

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 | string | |
| 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 |
| glyphs | array | only if the parent's format is glyphs |
| class | array | only if the parent's format is class |
| coverage | array | only if the parent's format is coverage |
| reversecoverage | array | only if the parent's format is reversecoverage |

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 |

for coverage:

| KEY | TYPE | EXPLANATION |
|---------|-------|-------------|
| current | array | of strings |
| before | array | of strings |
| after | array | of strings |

and for reverse coverage:

| KEY | TYPE | EXPLANATION |
|--------------|--------|-------------|
| current | array | of strings |
| before | array | of strings |
| after | array | of strings |
| replacements | string | |





260 The fontloader

13 The HarfBuzz libraries

13.1 The luaharfbuzz library

At the moment the documentation of the library is a raw "html-to-pdf" rendering of the `index.html` file under `luaharfbuzz/docs` folder of the source code. The example is almost the verbatim copy of the file under `luaharfbuzz/examples`.



Module harfbuzz

Lua bindings to Harfbuzz.

Info:

- **Copyright:** 2016
- **License:** MIT
- **Author:** Deepak Jois <deepak.jois@gmail.com>

Functions

| | |
|--|-------------------------------|
| <code>version ()</code> | Wraps <code>hb_version</code> |
| <code>shape (font, buffer[, options])</code> | Wraps <code>hb_shape</code> . |

Class Blob

| | |
|--|---|
| <code>Blob.new (data)</code> | Wraps <code>hb_blob_create</code> . |
| <code>Blob.new_from_file (filename)</code> | Wraps <code>hb_blob_create_from_file</code> . |
| <code>Blob:get_length ()</code> | Wraps <code>hb_blob_get_length</code> . |
| <code>Blob:get_data ()</code> | Wraps <code>hb_blob_get_data</code> . |

Class Face

| | |
|--|---|
| <code>Face.new_from_blob (blob[, font_index=0])</code> | Wraps <code>hb_face_create</code> . |
| <code>Face.new (file[, font_index=0])</code> | Create a new <code>Face</code> from a file. |
| <code>Face:collect_unicodes ()</code> | Wraps <code>hb_face_collect_unicodes</code> . |
| <code>Face:get_glyph_count ()</code> | Wraps <code>hb_face_get_glyph_count</code> . |
| <code>Face:get_table (tag)</code> | Wraps <code>hb_face_reference_table</code> . |
| <code>Face:get_table_tags ()</code> | Wraps <code>hb_face_get_table_tags</code> . |
| <code>Face:get_upem ()</code> | Wraps <code>hb_face_get_upem</code> . |
| <code>Face:ot_color_has_palettes ()</code> | Wraps <code>hb_ot_color_has_palettes</code> . |
| <code>Face:ot_color_palette_get_count ()</code> | Wraps <code>hb_ot_color_palette_get_count</code> . |
| <code>Face:ot_color_palette_get_colors ()</code> | Wraps <code>hb_ot_color_palette_get_colors</code> . |
| <code>Face:ot_color_has_layers ()</code> | Wraps <code>hb_ot_color_has_layers</code> . |
| <code>Face:ot_color_glyph_get_layers ()</code> | Wraps <code>hb_ot_color_glyph_get_layers</code> . |
| <code>Face:ot_color_has_png ()</code> | Wraps <code>hb_ot_color_has_png</code> . |
| <code>Face:ot_layout_get_script_tags ()</code> | Wraps <code>hb_ot_layout_table_get_script_tags</code> . |
| <code>Face:ot_layout_get_language_tags ()</code> | Wraps <code>hb_ot_layout_script_get_language_tags</code> . |
| <code>Face:ot_layout_get_feature_tags ()</code> | Wraps <code>hb_ot_layout_language_get_feature_tags</code> . |
| <code>Face:ot_layout_find_script ()</code> | Wraps <code>hb_ot_layout_table_find_script</code> . |
| <code>Face:ot_layout_find_language ()</code> | Wraps <code>hb_ot_layout_script_find_language</code> . |
| <code>Face:ot_layout_find_feature ()</code> | Wraps <code>hb_ot_layout_language_find_feature</code> . |

Class Font

| | |
|--|--|
| <code>Font.new (face)</code> | Wraps <code>hb_font_create</code> , and sets up some defaults for scale and shaping functions. |
| <code>Font:get_scale ()</code> | Wraps <code>hb_font_get_scale</code> . |
| <code>Font:set_scale (x_scale, y_scale)</code> | Wraps <code>hb_font_set_scale</code> . |
| <code>Font:get_h_extents ()</code> | Wraps <code>hb_font_get_h_extents</code> . |
| <code>Font:get_v_extents ()</code> | Wraps <code>hb_font_get_v_extents</code> . |
| <code>Font:get_glyph_extents (glyph)</code> | Wraps <code>hb_font_get_glyph_extents</code> . |



| | |
|--|------------------------------------|
| Font:get_glyph_name (glyph) | Wraps hb_font_get_glyph_name. |
| Font:get_glyph_from_name (name) | Wraps hb_font_get_glyph_from_name. |
| Font:get_glyph_h_advance (glyph) | Wraps hb_font_get_glyph_h_advance. |
| Font:get_glyph_v_advance (glyph) | Wraps hb_font_get_glyph_v_advance. |
| Font:get_nominal_glyph (codepoint.) | Wraps hb_font_get_nominal_glyph. |
| Font:ot_color_glyph_get_png () | Wraps hb_ot_color_glyph_get_png. |

Class Buffer

| | |
|--|---|
| Buffer.new () | Wraps hb_buffer_create. |
| Buffer:add_utf8 (text[, item_offset=0[, item_length=-1]]) | Wraps hb_buffer_add_utf8. |
| Buffer:add_codepoints (text[, item_offset=0[, item_length=-1]]) | Wraps hb_buffer_add_codepoints. |
| Buffer:set_direction (dir) | Wraps hb_buffer_set_direction. |
| Buffer:get_direction () | Wraps hb_buffer_get_direction. |
| Buffer:set_script (script) | Wraps hb_buffer_set_script. |
| Buffer:get_script () | Wraps hb_buffer_get_script. |
| Buffer:set_language (lang) | Wraps hb_buffer_set_language. |
| Buffer:get_language () | Wraps hb_buffer_get_language. |
| Buffer:reverse () | Wraps hb_buffer_reverse. |
| Buffer:get_length () | Wraps hb_buffer_get_length. |
| Buffer:get_cluster_level () | Wraps hb_buffer_get_cluster_level. |
| Buffer:set_cluster_level (level) | Wraps hb_buffer_set_cluster_level. |
| Buffer:guess_segment_properties () | Wraps hb_buffer_guess_segment_properties. |
| Buffer:get_glyphs () | Helper method to get shaped glyph data. |

Cluster Levels

| | |
|---|--|
| Buffer.CLUSTER_LEVEL_MONOTONE_GRAPHEMES | Wraps HB_BUFFER_CLUSTER_LEVEL_MONOTONE_GRAPHEMES. |
| Buffer.CLUSTER_LEVEL_MONOTONE_CHARACTERS | Wraps HB_BUFFER_CLUSTER_LEVEL_MONOTONE_CHARACTERS. |
| Buffer.CLUSTER_LEVEL_CHARACTERS | Wraps HB_BUFFER_CLUSTER_LEVEL_CHARACTERS. |
| Buffer.CLUSTER_LEVEL_DEFAULT | Wraps HB_BUFFER_CLUSTER_LEVEL_DEFAULT. |
| Buffer.GLYPH_FLAG_UNSAFE_TO_BREAK | Wraps HB_GLYPH_FLAG_UNSAFE_TO_BREAK. |
| Buffer.GLYPH_FLAG_DEFINED | Wraps HB_GLYPH_FLAG_DEFINED. |

Class Feature

| | |
|-------------------------------------|------------------------------|
| Feature.new (feature_string) | Wraps hb_feature_from_string |
| Feature: __tostring () | Wraps hb_feature_to_string. |

Class Tag

| | |
|----------------------------|--|
| Tag.new (string) | Wraps hb_tag_from_string. |
| Tag: __to_string () | Wraps hb_tag_to_string. |
| Tag: __eq () | Enables equality comparisons with == between two tags. |

Class Script

| | |
|---------------------------------------|-----------------------------------|
| Script.new (script) | Wraps hb_script_from_string. |
| Script.from_iso15924_tag (tag) | Wraps hb_script_from_iso15924_tag |



| | |
|----------------------------------|---|
| Script:to_iso15924_tag () | Wraps hb_script_to_iso15924_tag. |
| Script: __to_string () | Enable nice output with tostring(...) |
| Script: __eq () | Enables equality comparisons with == between two scripts. |

Predefined Script Codes

| | |
|-------------------------|----------------------------|
| Script.COMMON | Wraps HB_SCRIPT_COMMON. |
| Script.INHERITED | Wraps HB_SCRIPT_INHERITED. |
| Script.UNKNOWN | Wraps HB_SCRIPT_UNKNOWN. |
| Script.INVALID | Wraps HB_SCRIPT_INVALID. |

Class Direction

| | |
|-----------------------------------|--|
| Direction.new (dir) | Wraps hb_direction_from_string. |
| Direction: __to_string () | Wraps hb_direction_to_string. |
| Direction: __eq () | Enables equality comparisons with == between two directions. |
| Direction:is_valid () | Wraps HB_DIRECTION_IS_VALID. |
| Direction:is_horizontal () | Wraps HB_DIRECTION_IS_HORIZONTAL. |
| Direction:is_vertical () | Wraps HB_DIRECTION_IS_VERTICAL. |
| Direction:is_forward () | Wraps HB_DIRECTION_IS_FORWARD. |
| Direction:is_backward () | Wraps HB_DIRECTION_IS_BACKWARD. |

Predefined directions

| | |
|----------------------|-------------------------|
| Direction.LTR | Wraps HB_DIRECTION_LTR. |
| Direction.RTL | Wraps HB_DIRECTION_RTL. |
| Direction.TTB | Wraps HB_DIRECTION_TTB. |
| Direction.BTT | Wraps HB_DIRECTION_LTR. |

Class Language

| | |
|---------------------------------|---|
| Language.new (lang) | Wraps hb_language_from_string. |
| Language: __to_string () | Wraps hb_language_to_string. |
| Language: __eq () | Enables equality comparisons with == between two languages. |

Predefined languages

| | |
|-------------------------|----------------------------|
| Language.INVALID | Wraps HB_LANGUAGE_INVALID. |
|-------------------------|----------------------------|

Unicode functions

| | |
|------------------------------|-------------------------|
| unicode.script (char) | Wraps hb_unicode_script |
|------------------------------|-------------------------|

Predefined Name IDs

| | |
|-----------------------------------|-------------------------------------|
| ot.NAME_ID_COPYRIGHT | Wraps HB_OT_NAME_ID_COPYRIGHT |
| ot.NAME_ID_FONT_FAMILY | Wraps HB_OT_NAME_ID_FONT_FAMILY |
| ot.NAME_ID_FONT_SUBFAMILY | Wraps HB_OT_NAME_ID_FONT_SUBFAMILY |
| ot.NAME_ID_UNIQUE_ID | Wraps HB_OT_NAME_ID_UNIQUE_ID |
| ot.NAME_ID_FULL_NAME | Wraps HB_OT_NAME_ID_FULL_NAME |
| ot.NAME_ID_VERSION_STRING | Wraps HB_OT_NAME_ID_VERSION_STRING |
| ot.NAME_ID_POSTSCRIPT_NAME | Wraps HB_OT_NAME_ID_POSTSCRIPT_NAME |
| ot.NAME_ID_TRADEMARK | Wraps HB_OT_NAME_ID_TRADEMARK |
| ot.NAME_ID_MANUFACTURER | Wraps HB_OT_NAME_ID_MANUFACTURER |



| | |
|---|--|
| <code>ot.NAME_ID_DESIGNER</code> | Wraps <code>HB_OT_NAME_ID_DESIGNER</code> |
| <code>ot.NAME_ID_DESCRIPTION</code> | Wraps <code>HB_OT_NAME_ID_DESCRIPTION</code> |
| <code>ot.NAME_ID_VENDOR_URL</code> | Wraps <code>HB_OT_NAME_ID_VENDOR_URL</code> |
| <code>ot.NAME_ID_DESIGNER_URL</code> | Wraps <code>HB_OT_NAME_ID_DESIGNER_URL</code> |
| <code>ot.NAME_ID_LICENSE</code> | Wraps <code>HB_OT_NAME_ID_LICENSE</code> |
| <code>ot.NAME_ID_LICENSE_URL</code> | Wraps <code>HB_OT_NAME_ID_LICENSE_URL</code> |
| <code>ot.NAME_ID TYPOGRAPHIC_FAMILY</code> | Wraps <code>HB_OT_NAME_ID TYPOGRAPHIC_FAMILY</code> |
| <code>ot.NAME_ID TYPOGRAPHIC_SUBFAMILY</code> | Wraps <code>HB_OT_NAME_ID TYPOGRAPHIC_SUBFAMILY</code> |
| <code>ot.NAME_ID_MAC_FULL_NAME</code> | Wraps <code>HB_OT_NAME_ID_MAC_FULL_NAME</code> |
| <code>ot.NAME_ID_SAMPLE_TEXT</code> | Wraps <code>HB_OT_NAME_ID_SAMPLE_TEXT</code> |
| <code>ot.NAME_ID_CID_FINDFONT_NAME</code> | Wraps <code>HB_OT_NAME_ID_CID_FINDFONT_NAME</code> |
| <code>ot.NAME_ID_WWS_FAMILY</code> | Wraps <code>HB_OT_NAME_ID_WWS_FAMILY</code> |
| <code>ot.NAME_ID_WWS_SUBFAMILY</code> | Wraps <code>HB_OT_NAME_ID_WWS_SUBFAMILY</code> |
| <code>ot.NAME_ID_LIGHT_BACKGROUND</code> | Wraps <code>HB_OT_NAME_ID_LIGHT_BACKGROUND</code> |
| <code>ot.NAME_ID_DARK_BACKGROUND</code> | Wraps <code>HB_OT_NAME_ID_DARK_BACKGROUND</code> |
| <code>ot.NAME_ID_VARIATIONS_PS_PREFIX</code> | Wraps <code>HB_OT_NAME_ID_VARIATIONS_PS_PREFIX</code> |
| <code>ot.NAME_ID_INVALID</code> | Wraps <code>HB_OT_NAME_ID_INVALID</code> |
| <code>ot.LAYOUT_NO_SCRIPT_INDEX</code> | Wraps <code>HB_OT_LAYOUT_NO_SCRIPT_INDEX</code> |
| <code>ot.LAYOUT_NO_FEATURE_INDEX</code> | Wraps <code>HB_OT_LAYOUT_NO_FEATURE_INDEX</code> |
| <code>ot.LAYOUT_DEFAULT_LANGUAGE_INDEX</code> | Wraps <code>HB_OT_LAYOUT_DEFAULT_LANGUAGE_INDEX</code> |
| <code>ot.LAYOUT_NO_VARIATIONS_INDEX</code> | Wraps <code>HB_OT_LAYOUT_NO_VARIATIONS_INDEX</code> |

Functions

`version ()`

Wraps `hb_version`

`shape (font, buffer[, options])`

Wraps `hb_shape`.

Parameters:

- `font`: `Font` to use for shaping
- `buffer`: `Buffer` to shape
- `options`:

table containing one or more supported options:

- `direction`: A `Direction` object representing the object.
- `script`: A `Script` object representing the script.
- `language`: A `Language` object representing the language.
- `features`: features to enable, specified as either of the following.
 - comma-separated list of features. See [feature string syntax reference](#)
 - table of `Feature` objects

(*optional*)

Class Blob

Lua wrapper for `hb_blob_t` type

`Blob.new (data)`

Wraps `hb_blob_create`. Initializes a new `hb_blob_t`.



Parameters:

- `data`: lua string containing binary or character data.
-

Blob.new_from_file (filename)

Wraps `hb_blob_create_from_file`. Initializes a new `hb_blob_t`.

Parameters:

- `filename`: lua string.
-

Blob:get_length ()

Wraps `hb_blob_get_length`.

Blob:get_data ()

Wraps `hb_blob_get_data`.

Class Face

Lua wrapper for `hb_face_t` type

Face.new_from_blob (blob[, font_index=0])

Wraps `hb_face_create`. Initializes a new `hb_face_t` from a `Blob` object.

Parameters:

- `blob`: `Blob` to read the font from.
 - `font_index`: index of font to read. (*default 0*)
-

Face.new (file[, font_index=0])

Create a new `Face` from a file. Makes a call to `Face:new_from_blob` after creating a `Blob` from the file contents.

Parameters:

- `file`: path to font file.
 - `font_index`: index of font to read. (*default 0*)
-

Face:collect_unicodes ()

Wraps `hb_face_collect_unicodes`.

Returns:

table of codepoints supported by the face.

Face:get_glyph_count ()

Wraps `hb_face_get_glyph_count`.

Face:get_table (tag)

Wraps `hb_face_reference_table`.

Parameters:

- `tag`: `Tag` object of the table.

Returns:

`Blob` object for the face table of `tag`.



Face:get_table_tags ()

Wraps hb_face_get_table_tags.

Returns:

table of **Tags** representing face table tags.

Face:get_upem ()

Wraps hb_face_get_upem.

Face:ot_color_has_palettes ()

Wraps hb_ot_color_has_palettes.

Face:ot_color_palette_get_count ()

Wraps hb_ot_color_palette_get_count.

Face:ot_color_palette_get_colors ()

Wraps hb_ot_color_palette_get_colors.

Face:ot_color_has_layers ()

Wraps hb_ot_color_has_layers.

Face:ot_color_glyph_get_layers ()

Wraps hb_ot_color_glyph_get_layers.

Face:ot_color_has_png ()

Wraps hb_ot_color_has_png.

Face:ot_layout_get_script_tags ()

Wraps hb_ot_layout_table_get_script_tags.

Face:ot_layout_get_language_tags ()

Wraps hb_ot_layout_script_get_language_tags.

Face:ot_layout_get_feature_tags ()

Wraps hb_ot_layout_language_get_feature_tags.

Face:ot_layout_find_script ()

Wraps hb_ot_layout_table_find_script.

Face:ot_layout_find_language ()

Wraps hb_ot_layout_script_find_language.

Face:ot_layout_find_feature ()

Wraps hb_ot_layout_language_find_feature.



Class Font

Lua wrapper for `hb_font_t` type

Font.new (face)

Wraps `hb_font_create`, and sets up some defaults for scale and shaping functions. Initializes a new `hb_font_t` from a `Face` object. Sets the default scale to the face's upem value, and sets the font shaping functions by calling `hb_ot_font_set_funcs` on it.

Parameters:

- `face`: `Face` object.
-

Font:get_scale ()

Wraps `hb_font_get_scale`.

Returns:

two values for the x-scale and y-scale of the font.

Font:set_scale (x_scale, y_scale)

Wraps `hb_font_set_scale`.

Parameters:

- `x_scale`: desired x-scale of font.
 - `y_scale`: desired y-scale of font.
-

Font:get_h_extents ()

Wraps `hb_font_get_h_extents`.

Returns:

font extents table for horizontal direction, contains the following or `nil` if HarfBuzz fails to load font extents:

- `ascender`: typographic ascender.
 - `descender`: typographic descender.
 - `line_gap`: line spacing gap.
-

Font:get_v_extents ()

Wraps `hb_font_get_v_extents`.

Returns:

font extents table for vertical direction, similar to `Font:get_h_extents`, or `nil` if HarfBuzz fails to load font extents:

Font:get_glyph_extents (glyph)

Wraps `hb_font_get_glyph_extents`.

Parameters:

- `glyph`: index inside the font.

Returns:

extents table contains the following or `nil` if HarfBuzz fails to load glyph extents:

- `x_bearing`: left side of glyph from origin.
- `y_bearing`: top side of glyph from origin.
- `width`: distance from left to right side.
- `height`: distance from top to bottom side.



Font:get_glyph_name (glyph)

Wraps `hb_font_get_glyph_name`.

Parameters:

- `glyph`: index inside the font.

Returns:

name of the glyph or `nil`.

Font:get_glyph_from_name (name)

Wraps `hb_font_get_glyph_from_name`.

Parameters:

- `name`: of the glyph.

Returns:

glyph index inside the font or `nil`.

Font:get_glyph_h_advance (glyph)

Wraps `hb_font_get_glyph_h_advance`.

Parameters:

- `glyph`: index inside the font.

Returns:

advance glyph advance of the glyph in horizontal direction.

Font:get_glyph_v_advance (glyph)

Wraps `hb_font_get_glyph_v_advance`.

Parameters:

- `glyph`: index inside the font.

Returns:

advance glyph advance of the glyph in vertical direction.

Font:get_nominal_glyph (codepoint.)

Wraps `hb_font_get_nominal_glyph`.

Parameters:

- `codepoint`..:

Returns:

glyph index or `nil` if `codepoint` is not supported by the font.

Font:ot_color_glyph_get_png ()

Wraps `hb_ot_color_glyph_get_png`.

Class Buffer

Lua wrapper for `hb_buffer_t` type.



Buffer.new ()

Wraps `hb_buffer_create`.

Buffer:add_utf8 (text[, item_offset=0[, item_length=-1]])

Wraps `hb_buffer_add_utf8`.

Parameters:

- `text`: UTF8 encoded string.
 - `item_offset`: 0-indexed offset in `text`, from where to start adding. (*default* 0)
 - `item_length`: length to add from `item_offset`. -1 adds till end of `text`. (*default* -1)
-

Buffer:add_codepoints (text[, item_offset=0[, item_length=-1]])

Wraps `hb_buffer_add_codepoints`.

Parameters:

- `text`: table with codepoints as lua numbers.
 - `item_offset`: 0-indexed offset in `text`, from where to start adding. (*default* 0)
 - `item_length`: length to add from `item_offset`. -1 adds till end of `text`. (*default* -1)
-

Buffer:set_direction (dir)

Wraps `hb_buffer_set_direction`.

Parameters:

- `dir`: A `Direction` object.
-

Buffer:get_direction ()

Wraps `hb_buffer_get_direction`.

Returns:

A `Direction` object.

Buffer:set_script (script)

Wraps `hb_buffer_set_script`.

Parameters:

- `script`: A `Script` object.
-

Buffer:get_script ()

Wraps `hb_buffer_get_script`.

Returns:

A `Script` object.

Buffer:set_language (lang)

Wraps `hb_buffer_set_language`.

Parameters:

- `lang`: A `Language` object
-

Buffer:get_language ()

Wraps `hb_buffer_get_language`.

Returns:

A `Language` object

Buffer:reverse ()

Wraps `hb_buffer_reverse`.

Buffer:get_length ()

Wraps `hb_buffer_get_length`.

Buffer:get_cluster_level ()

Wraps `hb_buffer_get_cluster_level`.

Returns:

see [Cluster Levels](#)

Buffer:set_cluster_level (level)

Wraps `hb_buffer_set_cluster_level`.

Parameters:

- `level`: see [Cluster Levels](#)
-

Buffer:guess_segment_properties ()

Wraps `hb_buffer_guess_segment_properties`.

Buffer:get_glyphs ()

Helper method to get shaped glyph data. Calls `hb_buffer_get_glyph_infos`, `hb_buffer_get_glyph_positions` and `hb_glyph_info_get_glyph_flags`, and assembles the data into a Lua table.

Returns:

table containing data for each glyph, in a nested table. Each nested table contains the following:

- `x_advance`: horizontal advance.
- `y_advance`: vertical advance.
- `x_offset`: horizontal displacement.
- `y_offset`: vertical displacement.
- `cluster`: glyph cluster index within input.
- `codepoint`: glyph index inside the font (*this field name is a bit misleading, but that's what Harfbuzz uses*).
- `flags`: glyph flags

Cluster Levels

See [Harfbuzz docs](#) for more details about what each of these levels mean.

Buffer.CLUSTER_LEVEL_MONOTONE_GRAPHEMES

Wraps `HB_BUFFER_CLUSTER_LEVEL_MONOTONE_GRAPHEMES`.

Buffer.CLUSTER_LEVEL_MONOTONE_CHARACTERS

Wraps `HB_BUFFER_CLUSTER_LEVEL_MONOTONE_CHARACTERS`.



Buffer.CLUSTER_LEVEL_CHARACTERS

Wraps HB_BUFFER_CLUSTER_LEVEL_CHARACTERS.

Buffer.CLUSTER_LEVEL_DEFAULT

Wraps HB_BUFFER_CLUSTER_LEVEL_DEFAULT.

Buffer.GLYPH_FLAG_UNSAFE_TO_BREAK

Wraps HB_GLYPH_FLAG_UNSAFE_TO_BREAK.

Buffer.GLYPH_FLAG_DEFINED

Wraps HB_GLYPH_FLAG_DEFINED.

Class Feature

Lua wrapper for `hb_feature_t` type

Feature.new (feature_string)

Wraps `hb_feature_from_string`

Parameters:

- `feature_string`: See [feature string syntax reference](#)
-

Feature: __tostring ()

Wraps `hb_feature_to_string`. Enables nice output with `tostring(...)`.

Class Tag

Lua wrapper for `hb_tag_t` type.

Tag.new (string)

Wraps `hb_tag_from_string`.

Parameters:

- `string`: to be converted to a `Tag` object.

Returns:

a `Tag` object.

Tag: __to_string ()

Wraps `hb_tag_to_string`. Enable nice output with `tostring(...)`.

Returns:

Returns a string representation for the tag object.

Tag: __eq ()

Enables equality comparisons with `==` between two tags.

Returns:

`true` or `false` depending on whether the two tags are equal.



Class Script

Lua wrapper for `hb_script_t` type.

Script.new (script)

Wraps `hb_script_from_string`.

Parameters:

- `script`: 4-letter script code according to the [ISO 15924 standard](#).

Returns:

a `Script` object.

Script.from_iso15924_tag (tag)

Wraps `hb_script_from_iso15924_tag`

Parameters:

- `tag`: a `Tag` object representing a [ISO 15924 script](#).
-

Script.to_iso15924_tag ()

Wraps `hb_script_to_iso15924_tag`.

Returns:

a `Tag` object representing the script.

Script:__to_string ()

Enable nice output with `tostring(...)`

Returns:

Returns a 4-letter [ISO 15924 script code](#) for the script object.

Script:__eq ()

Enables equality comparisons with `==` between two scripts.

Returns:

`true` or `false` depending on whether the two scripts are equal.

Predefined Script Codes

Predefined directions that correspond to their original definitions in Harfbuzz.

Script.COMMON

Wraps `HB_SCRIPT_COMMON`.

Script.INHERITED

Wraps `HB_SCRIPT_INHERITED`.

Script.UNKNOWN

Wraps `HB_SCRIPT_UNKNOWN`.

Script.INVALID



Wraps `HB_SCRIPT_INVALID`.

Class Direction

Lua wrapper for `hb_direction_t` type.

Direction.new (dir)

Wraps `hb_direction_from_string`.

Parameters:

- `dir`: can be one of `ltr`, `rtl`, `ttb`, `btt` or `invalid`.

Returns:

a `Direction` object.

Direction:__to_string ()

Wraps `hb_direction_to_string`. Enable nice output with `tostring(...)`.

Returns:

Returns a string representation for direction.

Direction:__eq ()

Enables equality comparisons with `==` between two directions.

Returns:

`true` or `false` depending on whether the two tags are equal.

Direction:is_valid ()

Wraps `HB_DIRECTION_IS_VALID`.

Returns:

a boolean value

Direction:is_horizontal ()

Wraps `HB_DIRECTION_IS_HORIZONTAL`.

Returns:

a boolean value

Direction:is_vertical ()

Wraps `HB_DIRECTION_IS_VERTICAL`.

Returns:

a boolean value

Direction:is_forward ()

Wraps `HB_DIRECTION_IS_FORWARD`.

Returns:

a boolean value

Direction:is_backward ()



Wraps `HB_DIRECTION_IS_BACKWARD`.

Returns:

a boolean value

Predefined directions

Predefined directions that correspond to their original definitions in Harfbuzz.

Direction.LTR

Wraps `HB_DIRECTION_LTR`.

Direction.RTL

Wraps `HB_DIRECTION_RTL`.

Direction.TTB

Wraps `HB_DIRECTION_TTB`.

Direction.BTT

Wraps `HB_DIRECTION_LTR`.

Class Language

Lua wrapper for `hb_language_t` type.

Language.new (lang)

Wraps `hb_language_from_string`.

Parameters:

- `lang`: **three-letter language tag** to be converted to a `Language` object.

Returns:

a `Language` object.

Language:__to_string ()

Wraps `hb_language_to_string`. Enable nice output with `tostring(...)`.

Returns:

Returns a string representation for the language object.

Language:__eq ()

Enables equality comparisons with `==` between two languages.

Returns:

`true` or `false` depending on whether the two languages are equal.

Predefined languages

Predefined languages that correspond to their original definitions in Harfbuzz.

Language.INVALID

Wraps `HB_LANGUAGE_INVALID`.



Unicode functions

unicode.script (char)

Wraps `hb_unicode_script`

Parameters:

- `char`: Unicode codepoint

Returns:

a `Script` object.

Predefined Name IDs

Predefined OpenType 'name' table name identifier.

ot.NAME_ID_COPYRIGHT

Wraps `HB_OT_NAME_ID_COPYRIGHT`

ot.NAME_ID_FONT_FAMILY

Wraps `HB_OT_NAME_ID_FONT_FAMILY`

ot.NAME_ID_FONT_SUBFAMILY

Wraps `HB_OT_NAME_ID_FONT_SUBFAMILY`

ot.NAME_ID_UNIQUE_ID

Wraps `HB_OT_NAME_ID_UNIQUE_ID`

ot.NAME_ID_FULL_NAME

Wraps `HB_OT_NAME_ID_FULL_NAME`

ot.NAME_ID_VERSION_STRING

Wraps `HB_OT_NAME_ID_VERSION_STRING`

ot.NAME_ID_POSTSCRIPT_NAME

Wraps `HB_OT_NAME_ID_POSTSCRIPT_NAME`

ot.NAME_ID_TRADEMARK

Wraps `HB_OT_NAME_ID_TRADEMARK`

ot.NAME_ID_MANUFACTURER

Wraps `HB_OT_NAME_ID_MANUFACTURER`

ot.NAME_ID_DESIGNER

Wraps `HB_OT_NAME_ID_DESIGNER`

ot.NAME_ID_DESCRIPTION

Wraps `HB_OT_NAME_ID_DESCRIPTION`



ot.NAME_ID_VENDOR_URL

Wraps HB_OT_NAME_ID_VENDOR_URL

ot.NAME_ID_DESIGNER_URL

Wraps HB_OT_NAME_ID_DESIGNER_URL

ot.NAME_ID_LICENSE

Wraps HB_OT_NAME_ID_LICENSE

ot.NAME_ID_LICENSE_URL

Wraps HB_OT_NAME_ID_LICENSE_URL

ot.NAME_ID_TYPOGRAPHIC_FAMILY

Wraps HB_OT_NAME_ID_TYPOGRAPHIC_FAMILY

ot.NAME_ID_TYPOGRAPHIC_SUBFAMILY

Wraps HB_OT_NAME_ID_TYPOGRAPHIC_SUBFAMILY

ot.NAME_ID_MAC_FULL_NAME

Wraps HB_OT_NAME_ID_MAC_FULL_NAME

ot.NAME_ID_SAMPLE_TEXT

Wraps HB_OT_NAME_ID_SAMPLE_TEXT

ot.NAME_ID_CID_FINDFONT_NAME

Wraps HB_OT_NAME_ID_CID_FINDFONT_NAME

ot.NAME_ID_WWS_FAMILY

Wraps HB_OT_NAME_ID_WWS_FAMILY

ot.NAME_ID_WWS_SUBFAMILY

Wraps HB_OT_NAME_ID_WWS_SUBFAMILY

ot.NAME_ID_LIGHT_BACKGROUND

Wraps HB_OT_NAME_ID_LIGHT_BACKGROUND

ot.NAME_ID_DARK_BACKGROUND

Wraps HB_OT_NAME_ID_DARK_BACKGROUND

ot.NAME_ID_VARIATIONS_PS_PREFIX

Wraps HB_OT_NAME_ID_VARIATIONS_PS_PREFIX

ot.NAME_ID_INVALID

Wraps HB_OT_NAME_ID_INVALID



ot.LAYOUT_NO_SCRIPT_INDEX

Wraps HB_OT_LAYOUT_NO_SCRIPT_INDEX

ot.LAYOUT_NO_FEATURE_INDEX

Wraps HB_OT_LAYOUT_NO_FEATURE_INDEX

ot.LAYOUT_DEFAULT_LANGUAGE_INDEX

Wraps HB_OT_LAYOUT_DEFAULT_LANGUAGE_INDEX

ot.LAYOUT_NO_VARIATIONS_INDEX

Wraps HB_OT_LAYOUT_NO_VARIATIONS_INDEX

Last updated 2019-07-31 18:39:39



13.1.1 Example

The example is (a small modification of) the file `core_types.lua` and it requires the file `harfbuzz.lua`; both are under `luaharfbuzz` folder of the source code. The fonts `notonastaliq.ttf` and `amiri-regular.ttf` are under `luaharfbuzz/fonts`.

The file `harfbuzz.lua`:

```
local hb = require("luaharfbuzz")

-- special tags
hb.Tag.NONE = hb.Tag.new()

-- special script codes (ISO 15924)
hb.Script.COMMON = hb.Script.new("Zyyy")
hb.Script.INHERITED = hb.Script.new("Zinh")
hb.Script.UNKNOWN = hb.Script.new("Zzzz")
hb.Script.INVALID = hb.Script.from_iso15924_tag(hb.Tag.NONE)

-- directions
hb.Direction.INVALID = hb.Direction.new("invalid")
hb.Direction.LTR = hb.Direction.new("ltr")
hb.Direction.RTL = hb.Direction.new("rtl")
hb.Direction.TTB = hb.Direction.new("ttb")
hb.Direction.BTT = hb.Direction.new("btt")

-- special languages
hb.Language.INVALID = hb.Language.new()

hb.shape = function(font, buf, options)
  options = options or { }

  -- Apply options to buffer if they are set.
  if options.language then buf:set_language(options.language) end
  if options.script then buf:set_script(options.script) end
  if options.direction then buf:set_direction(options.direction) end

  -- Guess segment properties, in case all steps above have failed
  -- to set the right properties.
  buf:guess_segment_properties()

  local features = {}

  -- Parse features
  if type(options.features) == "string" then
    for fs in string.gmatch(options.features, '([^\,]+)') do
```



```

    local feature = hb.Feature.new(fs)
    if feature then
        table.insert(features, hb.Feature.new(fs))
    else
        error(string.format("Invalid feature string: '%s'", fs))
    end
end
elseif type(options.features) == "table" then
    features = options.features
elseif options.features then -- non-nil but not a string or table
    error("Invalid features option")
end

return hb.shape_full(font,buf,features,options.shapers or {})
end

-- For backward compatibility
hb.Buffer.HB_BUFFER_CLUSTER_LEVEL_MONOTONE_GRAPHEMES = hb.Buffer.CLUSTER_LEVEL_MONOTONE_GRAPHEMES
hb.Buffer.HB_BUFFER_CLUSTER_LEVEL_MONOTONE_CHARACTERS = hb.Buffer.CLUSTER_LEVEL_MONOTONE_CHARACTERS
hb.Buffer.HB_BUFFER_CLUSTER_LEVEL_CHARACTERS = hb.Buffer.CLUSTER_LEVEL_CHARACTERS
hb.Buffer.HB_BUFFER_CLUSTER_LEVEL_DEFAULT = hb.Buffer.CLUSTER_LEVEL_DEFAULT

hb.Tag.HB_TAG_NONE = hb.Tag.NONE

hb.Script.HB_SCRIPT_COMMON = hb.Script.COMMON
hb.Script.HB_SCRIPT_INHERITED = hb.Script.INHERITED
hb.Script.HB_SCRIPT_UNKNOWN = hb.Script.UNKNOWN
hb.Script.HB_SCRIPT_INVALID = hb.Script.INVALID

hb.Language.HB_LANGUAGE_INVALID = hb.Language.INVALID

hb.Direction.HB_DIRECTION_INVALID = hb.Direction.INVALID
hb.Direction.HB_DIRECTION_LTR = hb.Direction.LTR
hb.Direction.HB_DIRECTION_RTL = hb.Direction.RTL
hb.Direction.HB_DIRECTION_TTB = hb.Direction.TTB
hb.Direction.HB_DIRECTION_BTT = hb.Direction.BTT

hb.Direction.HB_DIRECTION_IS_VALID = hb.Direction.is_valid
hb.Direction.HB_DIRECTION_IS_HORIZONTAL = hb.Direction.is_horizontal
hb.Direction.HB_DIRECTION_IS_VERTICAL = hb.Direction.is_vertical
hb.Direction.HB_DIRECTION_IS_FORWARD = hb.Direction.is_forward
hb.Direction.HB_DIRECTION_IS_BACKWARD = hb.Direction.is_backward

```



```
hb.Buffer.get_glyph_infos_and_positions = hb.Buffer.get_glyphs
```

```
return hb
```

The example:

```
local harfbuzz = require('harfbuzz')

-- Harfbuzz API Version
print("Harfbuzz API version", harfbuzz.version())

-- Shapers available
print("Shapers:", harfbuzz.shapers())

-- harfbuzz.Face
local face = harfbuzz.Face.new('notonastaliq.ttf')
print('\nFace upem = '..face:get_upem())

-- harfbuzz.Font
local font = harfbuzz.Font.new(face)
local xs, xy = font:get_scale()
print("\nDefault font scale = X: "..xs..", Y: "..xy)

-- harfbuzz.Buffer
local text = "ج" -- U+06CC U+06C1
local buf = harfbuzz.Buffer.new()
buf:add_utf8(text)

-- harfbuzz.shape (Shapes text)
print("\nShaping '"..text..' set with Noto Nastaliq Urdu")
harfbuzz.shape(font, buf, { language = harfbuzz.Language.new("urd"),
script = harfbuzz.Script.new("Arab"), direction = harfbuzz.Direction.RTL})

local glyphs = buf:get_glyphs()
print("No. of glyphs", #glyphs)
for k,v in pairs(glyphs) do
  print(k)
  for k1,v1 in pairs(v) do
    print("",k1,v1)
  end
end

local opts = { language = harfbuzz.Language.new("eng"),
script = harfbuzz.Script.new("Latn"), direction = harfbuzz.Direction.LTR }

local amiri_face = harfbuzz.Face.new('amiri-regular.ttf')
local amiri_font = harfbuzz.Font.new(amiri_face)
```



```

-- shaping '123' w/o features
print("\nShaping '123' set with Amiri Regular and no features")
buf= harfbuzz.Buffer.new()
buf:add_utf8("123")
harfbuzz.shape(amiri_font, buf, opts)
glyphs = buf:get_glyphs()
for k,v in pairs(glyphs) do
  print(k)
  for k1,v1 in pairs(v) do
    print("",k1,v1)
  end
end
end

-- shaping '123' with '+numr' (numerators)
print("\nShaping '123' set with Amiri Regular with 'numr' feature turned on")
buf= harfbuzz.Buffer.new()
buf:add_utf8("123")
opts.features = "+numr"
harfbuzz.shape(amiri_font, buf, opts)
glyphs = buf:get_glyphs()
for k,v in pairs(glyphs) do
  print(k)
  for k1,v1 in pairs(v) do
    print("",k1,v1)
  end
end
end

```

The result:

```

Harfbuzz API version 2.6.4
Shapers:      graphite2      ot      fallback

```

Face upem = 2048

Default font scale = X: 2048, Y: 2048

Shaping '۱۲۳' set with Noto Nastaliq Urdu

No. of glyphs 4

```

1
  flags      1.0
  cluster    2
  codepoint  277
  x_advance  472.0
  y_advance  0.0
  x_offset   0.0
  y_offset   0.0

```



2
cluster 0
codepoint 19
x_advance 0.0
y_advance 0.0
x_offset 310.0
y_offset -383.0

3
cluster 0
codepoint 985
x_advance 0.0
y_advance 0.0
x_offset 0.0
y_offset 0.0

4
cluster 0
codepoint 316
x_advance 731.0
y_advance 0.0
x_offset 0.0
y_offset -68.0

Shaping '123' set with Amiri Regular and no features

1
cluster 0
codepoint 20
x_advance 1090.0
y_advance 0.0
x_offset 0.0
y_offset 0.0

2
cluster 1
codepoint 21
x_advance 1090.0
y_advance 0.0
x_offset 0.0
y_offset 0.0

3
cluster 2
codepoint 22
x_advance 1090.0
y_advance 0.0
x_offset 0.0
y_offset 0.0

Shaping '123' set with Amiri Regular with 'numr' feature turned on

1



```
cluster 0
codepoint 6673
x_advance 600.0
y_advance 0.0
x_offset 0.0
y_offset 0.0
```

2

```
cluster 1
codepoint 6674
x_advance 600.0
y_advance 0.0
x_offset 0.0
y_offset 0.0
```

3

```
cluster 2
codepoint 6675
x_advance 600.0
y_advance 0.0
x_offset 0.0
y_offset 0.0
```



14 The backend libraries

14.1 The pdf library

This library contains variables and functions that are related to the pdf backend. You can find more details about the expected values to setters in section 3.2.

14.1.1 mapfile, mapline

```
pdf.mapfile(<string> map file)
pdf.mapline(<string> map line)
```

These two functions can be used to replace primitives `\pdfmapfile` and `\pdfmapline` inherited from pdf \TeX . They expect a string as only parameter and have no return value. The first character in a map line can be -, + or = which means as much as remove, add or replace this line. They are not state setters but act immediately.

14.1.2 [set|get][catalog|info|names|trailer]

These functions complement the corresponding pdf backend token lists dealing with metadata. The value types are strings and they are written to the pdf file directly after the token registers set at the \TeX end are written.

14.1.3 [set|get][pageattributes|pageresources|pagesattributes]

These functions complement the corresponding pdf backend token lists dealing with page resources. The variables have no interaction with the corresponding pdf backend token register. They are written to the pdf file directly after the token registers set at the \TeX end are written.

14.1.4 [set|get][xformattributes|xformresources]

These functions complement the corresponding pdf backend token lists dealing with reuseable boxes and images. The variables have no interaction with the corresponding pdf backend token register. They are written to the pdf file directly after the token registers set at the \TeX end are written.

14.1.5 [set|get][major|minor]version

You can set both the major and minor version of the output. The major version is normally 1 but when set to 2 some data will not be written to the file in order to comply with the standard. What minor version you set depends on what pdf features you use. This is out of control of Lua \TeX .

One can set the major version number to 2 but we cannot guarantee that the engine adapts itself correctly, because there is no public and free specification that we know of. Also, user



constructed annotations are not checked and just passed to the file. On the other hand, the pdf that the engine generated is rather simple and not that version depending.

14.1.6 `getcreationdate`

This function returns a string with the date in the format that ends up in the pdf file, in this case it's: .

14.1.7 `[set|get]inclusionerrorlevel` and `[set|get]ignoreunknownimages`

These variable control how error in included image are treated. They are modeled after the pdfTeX equivalents.

14.1.8 `[set|get]suppressoptionalinfo`, `[set|get]trailerid`, `[set|get]omitcidset`, `[set|get]omitinfo`, `[set|get]omitmediabox`, `[set|get]omitprocset`, `[set|get]ptexprefix`

The optional info bitset (a number) determines what kind of info gets flushed. By default we flush all. See section 3.2.2 for more details.

You can set your own trailer id. This has to be string containing valid pdf array content with checksums.

The cidset, charset and info flags (numbers) disables inclusion of a so called CIDSet and CharSet entries, which can be handy when aiming at some of the many pdf substandards. The same is true for the ProcSet and PTEX prefix where setting this flag will force the use of a `_` instead if a `..`³

When it is omitted, one should provide the MediaBox via the page attribute options, because it is a mandate field. No checking is done.

14.1.9 `[set|get][obj|]compresslevel` and `[set|get]recompress`

These functions set the level stream compression. When object compression is enabled multiple objects will be packed in a compressed stream which saves space. The minimum values are 0, the maxima are 9.

When recompression is to 1 compressed objects will be decompressed and when compresslevel is larger than zero they will then be recompressed. This is mostly a debugging feature and should not be relied upon.

14.1.10 `[set|get]gentounicode`

This flag enables tounicode generation (like in pdfTeX). Normally the values are provided by the font loader.

³ In the info dictionary a period is valid pre version 2, but the underscore has to be used elsewhere. The prefix dates from the early days of pdfTeX and at that time using a period was considered okay. Later specifications clarified this.



14.1.11 [set|get]decimaldigits

These two functions set the accuracy of floats written to the pdf file. You can set any value but the backend will not go below 3 and above 6.

14.1.12 [set|get]pkresolution

These setter takes two arguments: the resolution and an optional zero or one that indicates if this is a fixed one. The getter returns these two values.

14.1.13 getlast[obj|link|annot] and getretval

These status variables are similar to the ones traditionally used in the backend interface at the \TeX end.

14.1.14 getmaxobjnum and getobjtype, getfontname, getfontobjnum, getfontsize, getxformname

These introspective helpers are mostly used when you construct pdf objects yourself and need for instance information about a (to be) embedded font.

14.1.15 [set|get]origin

This one is used to set the horizontal and/or vertical offset, a traditional backend property.

```
pdf.setorigin() -- sets both to 0pt
pdf.setorigin(tex.sp("1in")) -- sets both to 1in
pdf.setorigin(tex.sp("1in"),tex.sp("1in"))
```

The counterpart of this function returns two values.

14.1.16 [set|get]imageresolution

These two functions relate to the imageresolution that is used when the image itself doesn't provide a non-zero x or y resolution.

14.1.17 [set|get][link|dest|thread|xform]margin

These functions can be used to set and retrieve the margins that are added to the natural bounding boxes of the respective objects.

14.1.18 get[pos|hpos|vpos]

These functions get current location on the output page, measured from its lower left corner. The values return scaled points as units.



```
local h, v = pdf.getpos()
```

14.1.19 [has|get]matrix

The current matrix transformation is available via the `getmatrix` command, which returns 6 values: `sx`, `rx`, `ry`, `sy`, `tx`, and `ty`. The `hasmatrix` function returns `true` when a matrix is applied.

```
if pdf.hasmatrix() then
  local sx, rx, ry, sy, tx, ty = pdf.getmatrix()
  -- do something useful or not
end
```

14.1.20 print

You can print a string to the pdf document from within a `\latelua` call. This function is not to be used inside `\directlua` unless you know *exactly* what you are doing.

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

The optional parameter can be used to mimic the behavior of pdf literals: the `type` is `direct` or `page`.

14.1.21 immediateobj

This function creates a pdf object and immediately writes it to the pdf file. It is modelled after pdfTeX's `\immediate \pdfobj` primitives. All function variants return the object number of the newly generated object.

```
<number> n =
  pdf.immediateobj(<string> objtext)
<number> n =
  pdf.immediateobj("file", <string> filename)
<number> n =
  pdf.immediateobj("stream", <string> streamtext, <string> attrtext)
<number> n =
  pdf.immediateobj("streamfile", <string> filename, <string> attrtext)
```

The first version puts the `objtext` raw into an object. Only the object wrapper is automatically generated, but any internal structure (like `<<` `>>` dictionary markers) needs to be provided by the user. The second version with keyword `file` as first argument puts the contents of the file with name `filename` raw into the object. The third version with keyword `stream` creates a stream object and puts the `streamtext` raw into the stream. The stream length is automatically calculated. The optional `attrtext` goes into the dictionary of that object. The fourth version with keyword `streamfile` does the same as the third one, it just reads the stream data raw from a file.



An optional first argument can be given to make the function use a previously reserved pdf object.

```
<number> n =
  pdf.immediateobj(<integer> n, <string> objtext)
<number> n =
  pdf.immediateobj(<integer> n, "file", <string> filename)
<number> n =
  pdf.immediateobj(<integer> n, "stream", <string> streamtext, <string> attr-
text)
<number> n =
  pdf.immediateobj(<integer> n, "streamfile", <string> filename, <string> at-
trtext)
```

14.1.22 obj

This function creates a pdf object, which is written to the pdf file only when referenced, e.g., by `refobj()`.

All function variants return the object number of the newly generated object, and there are two separate calling modes. The first mode is modelled after pdf_TE_X's `\pdfobj` primitive.

```
<number> n =
  pdf.obj(<string> objtext)
<number> n =
  pdf.obj("file", <string> filename)
<number> n =
  pdf.obj("stream", <string> streamtext, <string> attrtext)
<number> n =
  pdf.obj("streamfile", <string> filename, <string> attrtext)
```

An optional first argument can be given to make the function use a previously reserved pdf object.

```
<number> n =
  pdf.obj(<integer> n, <string> objtext)
<number> n =
  pdf.obj(<integer> n, "file", <string> filename)
<number> n =
  pdf.obj(<integer> n, "stream", <string> streamtext, <string> attrtext)
<number> n =
  pdf.obj(<integer> n, "streamfile", <string> filename, <string> attrtext)
```

The second mode accepts a single argument table with key-value pairs.

```
<number> n = pdf.obj {
  type          = <string>,
  immediate     = <boolean>,
  objnum       = <number>,
```



```

attr          = <string>,
compresslevel = <number>,
objcompression = <boolean>,
file          = <string>,
string       = <string>,
nolength     = <boolean>,
}

```

The type field can have the values `raw` and `stream`, this field is required, the others are optional (within constraints). When `nolength` is set, there will be no `/Length` entry added to the dictionary.

Note: this mode makes `obj` look more flexible than it actually is: the constraints from the separate parameter version still apply, so for example you can't have both `string` and `file` at the same time.

14.1.23 `refobj`

This function, the Lua version of the `\pdfrefobj` primitive, references an object by its object number, so that the object will be written to the pdf file.

```
pdf.refobj(<integer> n)
```

This function works in both the `\directlua` and `\lualatex` environment. Inside `\directlua` a new whatsit node 'pdf_refobj' is created, which will be marked for flushing during page output and the object is then written directly after the page, when also the resources objects are written to the pdf file. Inside `\lualatex` the object will be marked for flushing.

This function has no return values.

14.1.24 `reserveobj`

This function creates an empty pdf object and returns its number.

```

<number> n = pdf.reserveobj()
<number> n = pdf.reserveobj("annot")

```

14.1.25 `getpageref`

The object number of a page can be fetched with this function. This can be a forward reference so when you ask for a future page, you do get a number back.

```
<number> n = pdf.getpageref(123)
```

14.1.26 `registerannot`

This function adds an object number to the `/Annots` array for the current page without doing anything else. This function can only be used from within `\lualatex`.



```
pdf.registerannot (<number> objnum)
```

14.1.27 newcolorstack

This function allocates a new color stack and returns it's id. The arguments are the same as for the similar backend extension primitive.

```
pdf.newcolorstack("0 g", "page", true) -- page|direct|origin
```

14.1.28 setfontattributes

This function will force some additional code into the font resource. It can for instance be used to add a custom ToUnicode vector to a bitmap file.

```
pdf.setfontattributes(<number> font id, <string> pdf code)
```

14.2 The pdfe library

14.2.1 Introduction

The pdfe library replaces the epdf library and provides an interface to pdf files. It uses the same code as is used for pdf image inclusion. The pplib library by Paweł Jackowski replaces the poppler (derived from xpdf) library.

A pdf file is basically a tree of objects and one descends into the tree via dictionaries (key/value) and arrays (index/value). There are a few topmost dictionaries that start at root that are accessed more directly.

Although everything in pdf is basically an object we only wrap a few in so called userdata Lua objects.

| pdf | Lua |
|------------|---|
| null | nil |
| boolean | boolean |
| integer | integer |
| float | number |
| name | string |
| string | string |
| array | array userdata |
| dictionary | dictionary userdata |
| stream | stream userdata (with related dictionary) |
| reference | reference userdata |

The regular getters return these Lua data types but one can also get more detailed information.

14.2.2 open, new, getstatus, close, unencrypt

A document is loaded from a file or string



```
<pdf document> = pdf.open(filename)
<pdf document> = pdf.new(somestring,somelength)
```

Such a document is closed with:

```
pdf.close(<pdf document>)
```

You can check if a document opened well by:

```
pdf.getstatus(<pdf document>)
```

The returned codes are:

| VALUE | EXPLANATION |
|-------|-----------------------------------|
| -2 | the document is (still) protected |
| -1 | the document failed to open |
| 0 | the document is not encrypted |
| 1 | the document has been unencrypted |

An encrypted document can be unencrypted by the next command where instead of either password you can give nil:

```
pdf.unencrypt(<pdf document>,userpassword,ownerpassword)
```

14.2.3 **getsize, getversion, getnofobjects, getnofpages, getmemoryusage**

A successfully opened document can provide some information:

```
bytes = getsize(<pdf document>)
major, minor = getversion(<pdf document>)
n = getnofobjects(<pdf document>)
n = getnofpages(<pdf document>)
bytes, waste = getmemoryusage(<pdf document>)
```

14.2.4 **get[catalog|trailer|info]**

For accessing the document structure you start with the so called catalog, a dictionary:

```
<pdf dictionary> = pdf.getcatalog(<pdf document>)
```

The other two root dictionaries are accessed with:

```
<pdf dictionary> = pdf.gettrailer(<pdf document>)
<pdf dictionary> = pdf.getinfo(<pdf document>)
```

14.2.5 **getpage, getbox**

A specific page can conveniently be reached with the next command, which returns a dictionary. The first argument is to be a page dictionary.




```
<pdf dictionary> = pdf.getpage(<pdf document>,pagenumber)
```

Another convenience command gives you the (bounding) box of a (normally page) which can be inherited from the document itself. An example of a valid box name is MediaBox.

```
box_dimens <array> = pdf.getbox(<pdf dictionary>,boxname)
```

14.2.6 get[string|integer|number|boolean|name], type

Common values in dictionaries and arrays are strings, integers, floats, booleans and names (which are also strings) and these are also normal Lua objects:

```
s = getstring (<pdf array|dictionary>,index|key)
i = getinteger(<pdf array|dictionary>,index|key)
n = getnumber (<pdf array|dictionary>,index|key)
b = getboolean(<pdf array|dictionary>,index|key)
n = getname   (<pdf array|dictionary>,index|key)
s = type      (<pdf array|dictionary|document|reference|stream)
```

The type returns a string describing the type of the object, i.e. "pdf.array", "pdf.dictionary", "pdf", "pdf.reference", "pdf.stream".

The getstring function has two extra variants:

```
s, h = getstring (<pdf array|dictionary>,index|key,false)
s     = getstring (<pdf array|dictionary>,index|key,true)
```

The first call returns the original string plus a boolean indicating if the string is hex encoded. The second call returns the unencoded string.

14.2.7 get[from][dictionary|array|stream]

Normally you will use an index in an array and key in a dictionary but dictionaries also accept an index. The size of an array or dictionary is available with the usual # operator.

```
<pdf dictionary> = getdictionary(<pdf array|dictionary>,index|key)
<pdf array>      = getarray      (<pdf array|dictionary>,index|key)
<pdf stream>,
<pdf dictionary> = getstream     (<pdf array|dictionary>,index|key)
```

These commands return dictionaries, arrays and streams, which are dictionaries with a blob of data attached.

Before we come to an alternative access mode, we mention that the objects provide access in a different way too, for instance this is valid:

```
print(pdf.open("foo.pdf").Catalog.Type)
```

At the topmost level there are Catalog, Info, Trailer and Pages, so this is also okay:



```
print(pdf.open("foo.pdf").Pages[1])
```

14.2.8 [open|close|readfrom|whole|]stream

Streams are sort of special. When your index or key hits a stream you get back a stream object and dictionary object. The dictionary you can access in the usual way and for the stream there are the following methods:

```
okay    = openstream(<pdf stream>,[decode])
         closestream(<pdf stream>)
str, n  = readfromstream(<pdf stream>)
str, n  = readwholestream(<pdf stream>,[decode])
```

You either read in chunks, or you ask for the whole. When reading in chunks, you need to open and close the stream yourself. The `n` value indicates the length read. The `decode` parameter controls if the stream data gets uncompressed.

As with dictionaries, you can access fields in a stream dictionary in the usual Lua way too. You get the content when you 'call' the stream. You can pass a boolean that indicates if the stream has to be decompressed.

14.2.9 getfrom[dictionary|array]

In addition to the interface described before, there is also a bit lower level interface available.

```
key, type, value, detail = getfromdictionary(<pdf dictionary>,index)
type, value, detail = getfromarray(<pdf array>,index)
```

| TYPE | MEANING | VALUE | DETAIL |
|------|------------|------------------|-----------------|
| 0 | none | nil | |
| 1 | null | nil | |
| 2 | boolean | boolean | |
| 3 | integer | integer | |
| 4 | number | float | |
| 5 | name | string | |
| 6 | string | string | hex |
| 7 | array | arrayobject | size |
| 8 | dictionary | dictionaryobject | size |
| 9 | stream | streamobject | dictionary size |
| 10 | reference | integer | |

A hex string is (in the pdf file) surrounded by `<>` while plain strings are bounded by `<>`.

14.2.10 [dictionary|array]totable

All entries in a dictionary or table can be fetched with the following commands where the return values are a hashed or indexed table.



```
hash = dictionarytotable(<pdf dictionary>)
list = arraytotable(<pdf array>)
```

You can get a list of pages with:

```
{ { <pdf dictionary>, size, objnum }, ... } = pagestotable(<pdf document>)
```

14.2.11 getfromreference

Because you can have unresolved references, a reference object can be resolved with:

```
type, <pdf dictionary|array|stream>, detail = getfromreference(<pdf reference>)
```

So, as second value you get back a new pdf userdata object that you can query.

14.3 Memory streams

The `pdf.new` that takes three arguments:

| VALUE | EXPLANATION |
|---------------------|---|
| <code>stream</code> | this is a (in low level Lua speak) light userdata object, i.e. a pointer to a sequence of bytes |
| <code>length</code> | this is the length of the stream in bytes (the stream can have embedded zeros) |
| <code>name</code> | optional, this is a unique identifier that is used for hashing the stream, so that multiple doesn't use more memory |

The third argument is optional. When it is not given the function will return an pdf document object as with a regular file, otherwise it will return a filename that can be used elsewhere (e.g. in the image library) to reference the stream as pseudo file.

Instead of a light userdata stream (which is actually fragile but handy when you come from a library) you can also pass a Lua string, in which case the given length is (at most) the string length.

The function returns an pdf object and a string. The string can be used in the `img` library instead of a filename. You need to prevent garbage collection of the object when you use it as image (for instance by storing it somewhere).

Both the memory stream and it's use in the image library is experimental and can change. In case you wonder where this can be used: when you use the `swiglib` library for `graphicmagick`, it can return such a userdata object. This permits conversion in memory and passing the result directly to the backend. This might save some runtime in one-pass workflows. This feature is currently not meant for production and we might come up with a better implementation.

14.4 The pdfscanner library

The `pdfscanner` library allows interpretation of pdf content streams and `/ToUnicode (cmap)` streams. You can get those streams from the pdf library, as explained in an earlier section. There is only a single top-level function in this library:



```
pdfscanner.scan (<pdf stream>, <table> operatortable, <table> info)
pdfscanner.scan (<pdf array>, <table> operatortable, <table> info)
pdfscanner.scan (<string>, <table> operatortable, <table> info)
```

The first argument should be a Lua string or a stream or array object coming from the pdf library. The second argument, `operatortable`, should be a Lua table where the keys are pdf operator name strings and the values are Lua functions (defined by you) that are used to process those operators. The functions are called whenever the scanner finds one of these pdf operators in the content stream(s). The functions are called with two arguments: the scanner object itself, and the info table that was passed are the third argument to `pdfscanner.scan`.

Internally, `pdfscanner.scan` loops over the pdf operators in the stream(s), collecting operands on an internal stack until it finds a pdf operator. If that pdf operator's name exists in `operatortable`, then the associated function is executed. After the function has run (or when there is no function to execute) the internal operand stack is cleared in preparation for the next operator, and processing continues.

The scanner argument to the processing functions is needed because it offers various methods to get the actual operands from the internal operand stack.

A simple example of processing a pdf's document stream could look like this:

```
local operatortable = { }

operatortable.Do = function(scanner,info)
    local resources = info.resources
    if resources then
        local val      = scanner:pop()
        local name     = val[2]
        local xobject = resources.XObject
        print(info.space .. "Uses XObject " .. name)
        local resources = xobject.Resources
        if resources then
            local newinfo = {
                space      = info.space .. " ",
                resources = resources,
            }
            pdfscanner.scan(entry, operatortable, newinfo)
        end
    end
end

local function Analyze(filename)
    local doc = pdf.open(filename)
    if doc then
        local pages = doc.Pages
        for i=1,#pages do
            local page = pages[i]
            local info = {
```



```

        space      = "  " ,
        resources = page.Resources,
    }
    print("Page " .. i)
    -- pdfscanner.scan(page.Contents,operatortable,info)
    pdfscanner.scan(page.Contents(),operatortable,info)
end
end
end
end
end

```

```
Analyze("foo.pdf")
```

This example iterates over all the actual content in the pdf, and prints out the found XObject names. While the code demonstrates quite some of the pdf functions, let's focus on the type pdfscanner specific code instead.

From the bottom up, the following line runs the scanner with the pdf page's top-level content given in the first argument.

The third argument, `info`, contains two entries: `space` is used to indent the printed output, and `resources` is needed so that embedded XForms can find their own content.

The second argument, `operatortable` defines a processing function for a single pdf operator, `Do`.

The function `Do` prints the name of the current XObject, and then starts a new scanner for that object's content stream, under the condition that the XObject is in fact a `/Form`. That nested scanner is called with new `info` argument with an updated `space` value so that the indentation of the output nicely nests, and with a new `resources` field to help the next iteration down to properly process any other, embedded XObjects.

Of course, this is not a very useful example in practice, but for the purpose of demonstrating pdfscanner, it is just long enough. It makes use of only one scanner method: `scanner:pop()`. That function pops the top operand of the internal stack, and returns a Lua table where the object at index one is a string representing the type of the operand, and object two is its value.

The list of possible operand types and associated Lua value types is:

| TYPES | TYPE |
|----------|-----------|
| integer | <number> |
| real | <number> |
| boolean | <boolean> |
| name | <string> |
| operator | <string> |
| string | <string> |
| array | <table> |
| dict | <table> |

In case of `integer` or `real`, the value is always a Lua (floating point) number. In case of `name`, the leading slash is always stripped.



In case of `string`, please bear in mind that pdf actually supports different types of strings (with different encodings) in different parts of the pdf document, so you may need to reencode some of the results; pdfscanner always outputs the byte stream without reencoding anything. pdfscanner does not differentiate between literal strings and hexadecimal strings (the hexadecimal values are decoded), and it treats the stream data for inline images as a string that is the single operand for EI.

In case of `array`, the table content is a list of `pop` return values and in case of `dict`, the table keys are pdf name strings and the values are `pop` return values.

There are a few more methods defined that you can ask scanner:

| METHOD | EXPLANATION |
|----------------------------|--|
| <code>pop</code> | see above |
| <code>popnumber</code> | return only the value of a real or integer |
| <code>popname</code> | return only the value of a name |
| <code>popstring</code> | return only the value of a string |
| <code>poparray</code> | return only the value of a array |
| <code>popdictionary</code> | return only the value of a dict |
| <code>popboolean</code> | return only the value of a boolean |
| <code>done</code> | abort further processing of this scan() call |

The `pop*` are convenience functions, and come in handy when you know the type of the operands beforehand (which you usually do, in pdf). For example, the `Do` function could have used `local name = scanner:popname()` instead, because the single operand to the `Do` operator is always a pdf name object.

The `done` function allows you to abort processing of a stream once you have learned everything you want to learn. This comes in handy while parsing `/ToUnicode`, because there usually is trailing garbage that you are not interested in. Without `done`, processing only ends at the end of the stream, possibly wasting cpu cycles.

We keep the older names `popNumber`, `popName`, `popString`, `popArray`, `popDict` and `popBool` around.



Topics

a

Aleph 45, 54
adjust 134
attributes 24, 160, 198

b

backend 38, 46, 285
banner 21
boundary 138
boxes 19, 24, 201
 reuse 202
 split 202
bytecodes 191

c

callbacks 173
 building pages 179
 closing files 177
 contributions 178, 181
 data files 175
 dump 184
 editing 187
 errors 185, 186
 files 186
 font files 174, 175
 fonts 188, 189
 format file 174
 hyphenation 183
 image content 188
 image files 176
 input buffer 178
 inserts 179
 job run 185
 jobname 178
 kerning 184
 ligature building 183
 linebreaks 180, 181
 math 184
 opening files 176
 output 183
 output buffer 178
 output file 174
 pdf file 187

packing 181, 182

pages 185
reader 176
readers 177
rules 183
synctex 187
wrapping up 187

catcodes 29

characters 73
 codes 200

command line 61

conditions 35

configuration 217

convert commands 197

csnames 58

d

direct nodes 163

directions 54, 138

discretionaries 83, 87, 134

e

ϵ -T_EX 42

engines 41

errors 30, 31, 208

escaping 27

exceptions 81

expansion 34

f

files

 binary 59

 finding 227

 map 285

 names 39

 recording 226

 writing 39

fontloader

 tables 245

fonts 31, 91

 current 104

 define 103

 defining 210



- extend 103
- id 103, 104
- information 243
- iterate 104
- library 101
- loading 243
- real 96
- tables 91
- tfm 101
- used 323
- vf 102
- virtual 96, 98, 100, 102

format 22, 59

g

- glue 135
- glyphs 73, 136
- graphics 231

h

- hash 209
- helpers 207
- history 41
- hyperlinks 59
- hyphenation 37, 73, 79, 81
 - discretionaries 83
 - exceptions 81
 - how it works 83
 - patterns 81

i

- io 219
- images 231
 - immediate 234
 - injection 234
 - library 231
 - MetaPost 236
 - mplib 236
 - object 234
 - types 235
- initialization 61, 210
 - bitmaps 228
- insertions 133

k

- kerning 85

- kerns 136
 - suppress 31

l

- Lua 19
 - byte code 61
 - extensions 64
 - interpreter 61
 - libraries 64, 70
 - modules 70
- languages 37, 73
 - library 87
- last items 198
- leaders 37
- libraries
 - kpse 226
 - lua 191
 - status 192
 - tex 194
 - texconfig 217
 - texio 219
 - token 219
- ligatures 85
 - suppress 31
- linebreaks 87, 214
- lists 132, 204

m

- MetaPost 236
 - mplib 236
- macros 223
- main loop 79
- map files 285
- marks 33, 133
- math 30, 39, 107
 - accents 123
 - codes 127
 - cramped 110
 - delimiters 124, 126
 - extensibles 124
 - fences 122
 - flattening 129
 - fractions 126
 - italics 120
 - kerning 120
 - last line 127



limits 119
nodes 134, 139
parameters 112, 113, 203
penalties 121
radicals 124
scripts 120, 124, 128
spacing 110, 117, 118, 119
stacks 110
styles 109, 110, 128
text 129
tracing 129
Unicode 107
memory 58

n

nesting 204, 216
newline 59
nodes 19, 23, 131
 adjust 134
 attributes 160
 boundary 138
 direct 163
 direction 138
 discretionaries 134
 functions 149
 glue 135
 glyph 136
 insertions 133
 kerns 136
 lists 132
 marks 133
 math 134, 139
 paragraphs 138, 139
 penalty 136
 properties 168
 rules 132
 text 131

o

Omega 54
OpenType 243
output 36, 38

p

pdf 285
 analyze 291

 annotations 287, 290
 backend 46
 catalog 285
 color stack 291
 compression 286
 date 70, 286
 fonts 291
 info 285
 margins 287
 matrix 288
 memory streams 295
 objects 287, 288, 289, 290, 291
 options 286
 page attributes 285
 page resources 285
 pages 290
 positioning 287
 positions 287
 precision 287
 print to 288
 resolution 287
 scanner 295
 trailer 285, 286
 pdf 291
 unicode 286
 version 285
 xform attributes 285
 xform resources 285
pdfTeX 42
pages 202, 216
paragraphs 87, 138, 139
 reset 214
parameters
 internal 194
 math 203
patterns 81
penalty 136
primitives 31, 210
printing 205
properties 168
protrusion 139

r

registers 198, 201
 bytecodes 191
rules 37, 132



s

shipout 216
space 59
spaces
 suppress 32
splitting 36
synctex 216

t

\TeX 41
TrueType 243
Type1 245
testing 70
text
 math 129

tokens 219
 scanning 32
tracing 38

u

Unicode 22, 23
 math 107

v

version 21, 191

w

web2c 46



Primitives

This register contains the primitives that are mentioned in the manual. There are of course many more primitives. The LuaTeX primitives are typeset in bold. The primitives from pdfTeX are not supported that way but mentioned anyway.

| | | | |
|--------------------------------------|---------------------|--|---|
| <code>\abovedisplayskip</code> | 119 | <code>\csname</code> | 30, 33 |
| <code>\abovewithdelims</code> | 126 | <code>\csstring</code> | 33 |
| <code>\accent</code> | 35, 79, 80 | | |
| <code>\addafterocplist</code> | 45 | <code>\DefaultInputMode</code> | 45 |
| <code>\addbeforeocplist</code> | 45 | <code>\DefaultInputTranslation</code> | 45 |
| <code>\adjustspacing</code> | 43, 95 | <code>\DefaultOutputMode</code> | 45 |
| <code>\alignmark</code> | 33 | <code>\DefaultOutputTranslation</code> | 45 |
| <code>\aligntab</code> | 33 | <code>\def</code> | 49 |
| <code>\atop</code> | 110, 112 | <code>\delcode</code> | 58, 107, 200, 201 |
| <code>\atopwithdelims</code> | 110 | <code>\delimiter</code> | 107 |
| <code>\attribute</code> | 198 | <code>\detokenize</code> | 221 |
| <code>\attributedef</code> | 198 | <code>\dimen</code> | 23, 65, 198 |
| <code>\automaticdiscretionary</code> | 79 | <code>\dimendef</code> | 23, 198 |
| <code>\automatichyphenmode</code> | 77 | <code>\directlua</code> | 19 |
| <code>\automatichyphenpenalty</code> | 81 | <code>\directlua</code> | 21, 25, 26, 27, 191, 205, 210, 288, 290 |
| | | <code>\discretionary</code> | 20, 81, 82, 84, 134 |
| <code>\batchmode</code> | 219 | <code>\displaystyle</code> | 117 |
| <code>\beginscename</code> | 33 | <code>\displaywidowpenalties</code> | 215 |
| <code>\begingroup</code> | 110 | <code>\dp</code> | 23 |
| <code>\belowdisplayskip</code> | 119 | <code>\draftmode</code> | 39, 44 |
| <code>\bodydir</code> | 45 | | |
| <code>\bodydirection</code> | 57 | <code>\edef</code> | 28, 34, 49, 221 |
| <code>\boundary</code> | 38, 138 | <code>\efcode</code> | 22, 43, 95 |
| <code>\box</code> | 23 | <code>\endcsname</code> | 30 |
| <code>\boxdir</code> | 45 | <code>\endgroup</code> | 110 |
| <code>\breakafterdirmode</code> | 56 | <code>\endinput</code> | 219 |
| | | <code>\endlinechar</code> | 32, 41, 205, 206, 207 |
| <code>\catcode</code> | 21, 22, 58, 200 | <code>\errhelp</code> | 208 |
| <code>\catcodetable</code> | 29, 205 | <code>\errmessage</code> | 208 |
| <code>\char</code> | 20, 22, 80, 81, 136 | <code>\etoksapp</code> | 32 |
| <code>\chardef</code> | 22, 81, 223, 224 | <code>\etokspre</code> | 32 |
| <code>\clearmarks</code> | 33 | <code>\everyeof</code> | 32 |
| <code>\clearocplists</code> | 45 | <code>\everyjob</code> | 62 |
| <code>\clubpenalties</code> | 215 | <code>\exceptionpenalty</code> | 82 |
| <code>\copy</code> | 23 | <code>\exhyphenchar</code> | 80, 81 |
| <code>\copyfont</code> | 43 | <code>\exhyphenpenalty</code> | 81, 84, 134 |
| <code>\count</code> | 23, 24, 65, 198 | <code>\expandafter</code> | 34 |
| <code>\countdef</code> | 23, 198 | <code>\expanded</code> | 34, 43 |
| <code>\crampedscriptstyle</code> | 111 | | |



\expandglyphsinfont 44, 92, 93
\explicitdiscretionary 79
\explicithyphenpenalty 81
\externalocp 45

\firstvalidlanguage 74
\fontid 31
\formatname 22, 210

\gleaders 37
\glet 34
\global 58
\glyphdimensionsmode 38
\gtoksapp 32
\gtokspre 32

\halign 180
\hangindent 56
\hbox 20, 23, 36, 120, 180, 181, 201
\hjcode 22, 58, 74, 82
\hoffset 45
\hpack 36
\hrule 20
\hsize 78
\hskip 20, 135
\ht 23
\hyphenation 81, 84
\hyphenationbounds 76
\hyphenationmin 37, 74
\hyphenchar 80, 84, 91
\hyphenpenalty 81, 84, 134

\InputMode 45
\InputTranslation 45
\if 33
\ifabsdim 43
\ifabsnum 43
\ifcondition 35
\ifcsname 30
\ifincsname 43
\ifprimitive 43
\ifx 30
\ignoreligaturesinfont 43
\ignoreprimitiveerror 36, 186
\immediate 234, 235, 288
\immediateassigned 34

\immediateassignment 34
\initcatcodetable 29
\input 174
\insert 23, 133
\insertht 44
\interlinepenalties 215

\jobname 22, 62, 64, 178

\kern 20, 136
\knaccode 43
\knbccode 43
\knbscode 43

\language 80, 82, 84, 88
\lastnamedcs 33
\lastnodetype 131
\lastsavedboxresourceindex 37, 44
\lastsavedimageresourceindex 37, 44
\lastsavedimageresourcepages 37, 44
\lastxpos 44
\lastypos 44
\latelua 27, 144, 191, 288, 290
\lateluafunction 27
\lccode 22, 58, 200
\leaders 37
\left 122
\leftghost 74, 80
\lefthyphenmin 37, 74
\leftmarginkern 43
\letcharcode 33
\letterspacefont 43
\linedir 55
\localbrokenpenalty 138
\localinterlinepenalty 138
\localleftbox 138, 180
\localrightbox 138, 180
\long 30
\lowercase 82
\lpcode 22, 43, 94
\luabytecode 28
\luabytecodecall 28
\luacopyinputnodes 206
\luadef 27, 224
\luaescapestring 27
\luafunction 27



\luafunctioncall 27, 28
\luatexbanner 21
\luatexrevision 21, 22
\luatexversion 21, 22

\mag 41
\mark 133
\marks 23, 152
\mathaccent 107
\mathchar 107, 129
\mathchardef 107, 129
\mathchoice 109
\mathcode 58, 107, 200
\mathdefaultsmode 130
\mathdelimitersmode 122
\mathdir 45
\mathdir 57
\mathdir 205
\mathdirection 57
\mathdisplayskipmode 119
\mathemptydisplaymode 56
\matheqdirmode 119
\matheqnogapstep 122
\mathflattenmode 129
\mathitalicsmode 120, 122
\mathnolimitsmode 119, 120
\mathoption 130
\mathpenaltiesmode 121
\mathscriptboxmode 120
\mathscriptcharmode 120
\mathscriptsmode 121
\mathstyle 109, 110, 205
\mathsurround 117, 135
\mathsurroundmode 117
\mathsurroundskip 117
\maxdepth 182
\medmuskip 119
\middle 205
\muskip 23, 118, 119, 198
\muskipdef 23

\newlinechar 41
\noboundary 38, 80, 85, 138
\noDefaultInputMode 45
\noDefaultInputTranslation 45
\noDefaultOutputMode 45
\noDefaultOutputTranslation 45
\noexpand 34
\nohrule 37
\noInputMode 45
\noInputTranslation 45
\nokerns 31
\noligs 31
\noOutputMode 45
\noOutputTranslation 45
\nospaces 32
\novrule 37
\nullfont 30
\number 31, 208

\OutputMode 45
\OutputTranslation 45
\ocp 45
\ocplist 45
\ocptracelevel 45
\omathcode 45
\openin 174
\openout 39, 46, 174
\outer 30
\output 183, 193
\outputbox 36
\outputmode 38, 44
\over 110, 112, 205
\overline 111
\overwithdelims 110

\pagebottomoffset 45
\pagedir 45
\pagedir 57
\pagedirection 57
\pageheight 43, 45
\pagerightoffset 45
\pagewidth 43, 45
\par 24, 30, 179
\pardir 45
\pardir 57
\pardirection 57
\parfillskip 180, 215
\parindent 194
\parshape 56
\patterns 81, 83, 84
\pdfadjustinterwordglue 42



`\pdfappendkern` 43
`\pdfcopyfont` 43
`\pdfdraftmode` 44
`\pdfeachlinedepth` 43
`\pdfeachlineheight` 43
`\pdfelapsedtime` 43
`\pdfescapehex` 43
`\pdfescapename` 43
`\pdfescapestring` 43
`\pdfextension` 42, 47
`\pdffeedback` 42, 44, 47
`\pdffiledump` 43
`\pdffilemoddate` 43
`\pdffilesize` 43
`\pdffirstlineheight` 43
`\pdffontattr` 92
`\pdffontexpand` 44
`\pdfforcepagebox` 43
`\pdfignoreddimen` 43
`\pdfimageaddfilename` 44
`\pdfinsertht` 44
`\pdflastlinedepth` 43
`\pdflastmatch` 43
`\pdflastxform` 44
`\pdflastximage` 44
`\pdflastximagepages` 44
`\pdfliteral` 27
`\pdfmapfile` 285
`\pdfmapline` 285
`\pdfmatch` 43
`\pdfmdfivesum` 43
`\pdfmovechars` 43
`\pdfnoligatures` 43
`\pdfnormaldeviate` 43
`\pdfobj` 288, 289
`\pdfoptionalwaysusepdfpagebox` 43
`\pdfoptionpdfinclusionerrorlevel` 43
`\pdfoutput` 44
`\pdfpageheight` 43
`\pdfpagewidth` 43
`\pdfprependkern` 42
`\pdfpxdimen` 44
`\pdfrandomseed` 43
`\pdfrefobj` 290
`\pdfrefxform` 44
`\pdfrefximage` 44, 231
`\pdfresettimer` 43
`\pdfsetrandomseed` 43
`\pdfshellescape` 43
`\pdfsnaprefpoint` 42
`\pdfsnappy` 42
`\pdfsnappycomp` 42
`\pdfstrcmp` 43
`\pdftexbanner` 43
`\pdftexrevision` 43
`\pdftexversion` 43
`\pdftracingfonts` 44
`\pdfunescapehex` 43
`\pdfuniformdeviate` 43
`\pdfvariable` 42, 47, 231
`\pdfxform` 43, 44
`\pdfxformattr` 43
`\pdfxformresources` 43
`\pdfximage` 44, 231, 234
`\penalty` 136
`\popocplist` 45
`\postexhyphenchar` 79, 84
`\posthyphenchar` 84
`\preexhyphenchar` 79, 84
`\prehyphenchar` 84
`\primitive` 43
`\protrudechars` 43, 95
`\protrusionboundary` 38, 138
`\pushocplist` 45
`\pxdimen` 44
`\quitvmode` 43
`\radical` 107
`\read` 174
`\relax` 81, 206, 210, 222
`\removeafterocplist` 45
`\removebeforeocplist` 45
`\right` 122
`\rightghost` 74, 80
`\righthyphenmin` 37, 74
`\rightmarginkern` 43
`\romannumeral` 109, 208
`\rptide` 22, 43, 94
`\rule` 132
`\saveboxresource` 37, 44



\savecatcodetable 29, 30
\saveimageresource 37, 44, 235
\savepos 44
\savingshyphcodes 74, 75, 82, 89
\scantextokens 32
\scantokens 26, 32
\scriptfont 113
\scriptscriptfont 113
\scriptscriptstyle 124
\scriptspace 117
\scriptstyle 111
\setbox 23
\setfontid 31
\setlanguage 74, 80, 84
\sfcode 22, 58, 200
\shapemode 56
\shbscode 43
\shipout 185
\skewchar 91, 123
\skip 23, 198, 199
\skipdef 23, 198
\spaceskip 32
\special 99, 144
\stbscode 43
\string 33
\suppressfontnotfounderror 30
\suppressifcsnameerror 30
\suppresslongerror 30
\suppressmathparerror 30
\suppressoutererror 30
\suppressprimitiveerror 31

\tagcode 43
\textdir 45, 55
\textdir 57, 138
\textdir 205
\textdir(ection) 20
\textdirection 57
\textfont 113, 129
\textstyle 109
\the 22, 24, 31, 194, 197, 198, 205
\thickmuskip 119
\thinmuskip 119
\toks 23, 197, 198, 205
\toksapp 32
\toksdef 23, 198

\tokspre 32
\tpack 36
\tracingassigns 42, 58
\tracingcommands 81, 194
\tracingfonts 39, 44
\tracingnesting 209
\tracingonline 38
\tracingoutput 185
\tracingrestores 42, 58

\Uchar 23
\Udelcode 108, 201
\Udelcodenum 108
\Udelimiter 108
\Udelimiterover 108, 124
\Udelimiterunder 108, 124
\Uhexensible 125
\Umathaccent 108, 123
\Umathaxis 112
\Umathbinbinspacing 118
\Umathbinclonespacing 118
\Umathbininnerspacing 118
\Umathbinopenspacing 118
\Umathbinopspacing 118
\Umathbinordspacing 118
\Umathbinpunctspacing 118
\Umathbinrelspacing 118
\Umathchar 108, 129
\Umathchardef 107, 129
\Umathcharnum 108
\Umathcharnumdef 107, 108
\Umathclosebinspacing 118
\Umathcloseclonespacing 118
\Umathcloseinnerspacing 118
\Umathcloseopenspacing 118
\Umathcloseopspacing 118
\Umathcloseordspacing 118
\Umathclosepunctspacing 118
\Umathcloserelspacing 118
\Umathcode 108
\Umathcodenum 108
\Umathconnectoroverlapmin 113, 117
\Umathfractiondelsize 112
\Umathfractiondenomdown 112
\Umathfractiondenomvgap 112
\Umathfractionnumup 112



`\Umathfractionnumvgap` 112
`\Umathfractionrule` 112
`\Umathinnerbinspacing` 118
`\Umathinnerclosespacing` 118
`\Umathinnerinnerspacing` 118
`\Umathinneropenspacing` 118
`\Umathinnerordspacing` 118
`\Umathinnerordspacing` 118
`\Umathinnerpunctspacing` 118
`\Umathinnerrelspacing` 118
`\Umathlimitabovebgap` 112
`\Umathlimitabovekern` 112, 116
`\Umathlimitabovevgap` 112
`\Umathlimitbelowbgap` 112
`\Umathlimitbelowkern` 112, 116
`\Umathlimitbelowvgap` 112
`\Umathnolimitsubfactor` 119
`\Umathnolimitsupfactor` 119
`\Umathopbinspacing` 118
`\Umathopclosespacing` 118
`\Umathopenbinspacing` 118
`\Umathopenclosespacing` 118
`\Umathopeninnerspacing` 118
`\Umathopenopenspacing` 118
`\Umathopenopspacing` 118
`\Umathopenordspacing` 118
`\Umathopenpunctspacing` 118
`\Umathopenrelspacing` 118
`\Umathoperatorsize` 108, 112, 117
`\Umathopinnerspacing` 118
`\Umathopopenspacing` 118
`\Umathopopspacing` 118
`\Umathopordspacing` 118
`\Umathoppunctspacing` 118
`\Umathoprelspacing` 118
`\Umathordbinspacing` 118
`\Umathordclosespacing` 118
`\Umathordinnerspacing` 118
`\Umathordopenspacing` 118
`\Umathordopspacing` 118
`\Umathordordspacing` 118
`\Umathordpunctspacing` 118
`\Umathordrelspacing` 118
`\Umathoverbarkern` 112
`\Umathoverbarrule` 112
`\Umathoverbarvgap` 112
`\Umathoverdelimiterbgap` 112, 125
`\Umathoverdelimitervgap` 112, 125
`\Umathpunctbinspacing` 118
`\Umathpunctclosespacing` 118
`\Umathpunctinnerspacing` 118
`\Umathpunctopenspacing` 118
`\Umathpunctopspacing` 118
`\Umathpunctordspacing` 118
`\Umathpunctpunctspacing` 118
`\Umathpunctrelspacing` 118
`\Umathquad` 112, 116
`\Umathradicaldegreeafter` 112, 116, 124
`\Umathradicaldegreebefore` 112, 116, 124
`\Umathradicaldegreeraise` 112, 116, 117, 124
`\Umathradicalkern` 112
`\Umathradicalrule` 112, 116
`\Umathradicalvgap` 112, 116
`\Umathrelbinspacing` 118
`\Umathrelclosespacing` 118
`\Umathrelinnerspacing` 118
`\Umathreloppspacing` 118
`\Umathrelordspacing` 118
`\Umathrelpunctspacing` 118
`\Umathrelrelspacing` 118
`\Umathskewedfractionhgap` 126
`\Umathskewedfractionvgap` 126
`\Umathspaceafterscript` 113, 116, 117
`\Umathstackdenomdown` 112
`\Umathstacknumup` 112
`\Umathstackvgap` 112
`\Umathsubshiftdown` 113, 121
`\Umathsubshiftdrop` 113
`\Umathsubsupshiftdown` 113, 121
`\Umathsubsupvgap` 113
`\Umathsubtopmax` 113
`\Umathsupbottommin` 113
`\Umathsupshiftdrop` 113
`\Umathsupshiftdown` 113, 121
`\Umathsupsubbottommax` 113
`\Umathunderbarkern` 112
`\Umathunderbarrule` 112
`\Umathunderbarvgap` 112
`\Umathunderdelimiterbgap` 113, 125
`\Umathunderdelimitervgap` 113, 125



\Umath* 112
\Umiddle 126
\Unosubscript 128
\Unosuperscript 128
\Uoverdelimit 108, 124, 125
\Uradical 108, 124
\Uright 126
\Uroot 108, 124, 142
\Ustack 110
\Ustartdisplaymath 128
\Ustartmath 128
\Ustopdisplaymath 128
\Ustopmath 128
\Usubscript 128
\Usuperscript 128
\Uunderdelimit 108, 124, 125
\uccode 22, 58, 200
\uchyph 74, 137
\unexpanded 221
\unhbox 23
\unhcopy 23
\unvbox 23
\unvcopy 23
\uppercase 33, 82
\useboxresource 37, 44, 202
\useimageresource 37, 44, 235
\vadjust 134, 179, 204
\valign 180
\variablefam 108
\vbox 20, 23, 36, 180, 201, 215
\vcenter 180
\voffset 45
\vpack 36
\vrule 20
\vskip 20, 135
\vsplit 23, 36, 180, 202
\vtop 20, 36, 180, 201

\wd 23
\widowpenalties 215
\wordboundary 38, 75, 138
\write 27, 62, 174, 178

\xtoksapp 32
\xtokspre 32

\- 79, 81, 134





Callbacks

b

buildpage_filter 179
build_page_insert 179

c

call_edit 187
contribute_filter 178

d

define_font 91, 98, 188

f

find_data_file 175
find_enc_file 175
find_font_file 174, 175
find_format_file 174
find_image_file 176
find_map_file 175
find_opentype_file 175
find_output_file 174
find_pk_file 175
find_read_file 174, 176
find_truetype_file 175
find_typed1_file 175, 176
find_vf_file 175
find_write_file 174
finish_pdfpage 187
finish_pdfpage 187
finish_synctex 187

g

glyph_info 189
glyph_not_found 189

h

hpack_filter 180, 181, 182
hyphenate 183

k

kerning 184, 249

l

ligaturing 183, 184
linebreak_filter 181, 215

m

mlist_to_hlist 122, 154, 184

o

open_read_file 176

p

page_order_index 187
post_linebreak_filter 181
pre_dump 184
pre_linebreak_filter 180, 215
process_input_buffer 178
process_jobname 178
process_output_buffer 178
process_pdf_image_content 188
process_rule 183
provide_charproc_data 189

s

show_error_hook 185
show_error_message 186
show_ignored_error_message 186
show_lua_error_hook 186
start_file 186
start_page_number 185
start_run 185
stop_file 186
stop_page_number 185
stop_run 185

v

vpack_filter 180, 182

w

wrapup_run 187





Nodes

This register contains the nodes that are known to Lua_T_EX. The primary nodes are in bold, whatsits that are determined by their subtype are normal. The names prefixed by pdf_ are backend specific.

a

accent 141
adjust 76, 134
attr 161
attribute_list 160, 161

b

boundary 38, 76, 138

c

choice 141
close 143
color_stack 131

d

delim 140
delta 207
dir 20, 76, 131, 138
disc 20, 23, 134

f

fence 142
fraction 123, 142

g

glue 20, 23, 76, 131, 135
glue_spec 135, 194, 197, 198, 199
glyph 20, 23, 73, 74, 79, 136, 156

h

hlist 20, 23, 24, 25, 76, 132, 157

i

ins 76, 133

k

kern 20, 23, 76, 136

l

late_lua 144
local_par 138, 215

m

marginkern 139
mark 133, 254
math 134, 258
math_char 139
math_text_char 139

n

noad 141

o

open 143

p

pdf_action 131, 146
pdf_annot 145
pdf_colorstack 147
pdf_dest 146
pdf_end_link 146
pdf_end_thread 147
pdf_late_literal 145
pdf_literal 131, 145
pdf_refobj 145
pdf_restore 148
pdf_save 148
pdf_setmatrix 148
pdf_start_link 145
pdf_start_thread 147
pdf_thread 147
pdf_window 131
penalty 76, 136

r

radical 142



rule 20, 76, 101, 132

s

save_pos 144

special 144

style 141

sub_box 139, 140

sub_mlist 139, 140

t

temp 132

u

unset 148, 248, 258

user_defined 143

v

vlist 20, 23, 76, 132, 157

w

whatsit 76, 150

write 143



Libraries

This register contains the functions available in libraries. Not all functions are documented, for instance because they can be experimental or obsolete.

callback

- find 173
- list 173
- register 173

fio

- getposition 69
- readbytes 69
- readbytetable 69
- readcardinaltable 69
- readcardinal1 69
- readcardinal2 69
- readcardinal3 69
- readcardinal4 69
- readfixed2 69
- readfixed4 69
- readintegertable 69
- readinteger1 69
- readinteger2 69
- readinteger3 69
- readinteger4 69
- read2dot14 69
- setposition 69
- skipposition 69

fontloader

- apply_afmfile 245
- apply_featurefile 245
- close 243
- fields 245
- info 243
- open 243
- to_table 243

img

- boxes 235
- copy 234
- fields 232
- immediatewrite 234
- immediatewriteobject 234
- new 231
- node 235
- scan 233

- types 235

- write 234

kpse

- check_permission 230
- default_texmfcnf 226
- expand_braces 229
- expand_path 228
- expand_var 228
- find_file 227
- init_prog 228
- in_name_ok 229
- in_name_ok_silent_extended 229
- lookup 227
- new 226
- out_name_ok 229
- out_name_ok_silent_extended 229
- readable_file 228
- record_input_file 226
- record_output_file 226
- set_program_name 226
- show_path 229
- var_value 229
- version 230

lang

- clean 88
- clear_hyphenation 88
- clear_patterns 88
- gethjcode 89
- hyphenate 89
- hyphenation 88
- hyphenationmin 88
- id 87
- new 87
- patterns 88
- postexhyphenchar 88
- posthyphenchar 88
- preexhyphenchar 88
- prehyphenchar 88
- sethjcode 89



lua

bytecode 191
getbytecode 191
getcalllevel 192
getluaname 191
getstacktop 192
name 191
setbytecode 191
setluaname 191
version 191

mplib

char_depth 242
char_height 242
char_width 242
execute 237
fields 238
finish 237
get_boolean 242
get_numeric 242
get_path 242
get_string 242
new 236
pen_info 241
statistics 237
version 236

node

check_discretionaries 162, 165
check_discretionary 162, 165
copy 151, 165
copy_list 151, 165
count 155, 165
current_attr 151, 165
dimensions 153, 165
effective_glue 165
end_of_math 157, 165
family_font 162, 165
fields 131, 150, 165
find_attribute 161, 165
first_glyph 158, 165
fix_node_lists 165
flatten_discretionaries 162, 165
flush_list 150, 165
flush_node 150, 165
flush_properties_table 165, 168
free 150, 165
getboth 165

getchar 165
getdisc 165
getfield 165
getfont 165
getglue 160, 165
getid 165
getleader 166
getlist 166
getnext 166
getprev 166
getproperty 166
getsubtype 166
getwhd 166
get_attribute 161, 165
get_properties_table 165, 168
has_attribute 161, 166
has_field 150, 166
has_glyph 157, 166
hpack 152, 166
id 149, 166
insert_after 158, 166
insert_before 157, 166
is_char 155, 166
is_glyph 155, 166
is_node 149, 166
is_zero_glue 160, 166
kerning 158, 166
last_node 159, 166
length 155, 166
ligaturing 158, 166
make_extensible 166
mlist_to_hlist 154, 166
new 150, 166
next 151, 166
prepend_prevdepth 153, 166
prev 151, 166
protect_glyph 159, 166
protect_glyphs 159, 166
protrusion_skippable 159, 166
rangedimensions 153, 166
remove 157, 166
setfield 167
setglue 159, 167
setproperty 167
set_attribute 161, 166
set_properties_mode 166, 168



slide 162, 167
 subtype 149, 167
 subtypes 131, 167
 tail 154, 167
 todirect 163
 tonode 163
 tostring 163, 167
 traverse 155, 168
 traverse_char 156, 167
 traverse_glyph 156, 167
 traverse_id 156, 167
 traverse_list 157
 type 149, 168
 types 149, 168
 unprotect_glyph 159, 168
 unprotect_glyphs 159, 168
 unset_attribute 162, 168
 usedlist 168
 uses_font 168
 values 131, 168
 vpack 152, 168
 whatsits 149, 168
 write 159, 168
node.direct
 check_discretionaries 165
 check_discretionary 165
 copy 165
 copy_list 165
 count 165
 current_attr 165
 dimensions 165
 effective_glue 165
 end_of_math 165
 find_attribute 165
 first_glyph 165
 flatten_discretionaries 165
 flush_list 165
 flush_node 165
 flush_properties_table 165
 free 165
 getattributelist 165
 getboth 165
 getbox 165
 getchar 165
 getcomponents 165
 getdata 165
 getdepth 165
 getdir 165
 getdirection 165
 getdisc 165
 getexpansion 165
 getfam 165
 getfield 165
 getfont 165
 getglue 165
 getheight 165
 getid 165
 getkern 166
 getlang 166
 getleader 166
 getlist 166
 getnext 166
 getnucleus 166
 getoffsets 166
 getpenalty 166
 getprev 166
 getproperty 166
 getshift 166
 getsub 166
 getsubtype 166
 getsup 166
 getwhd 166
 getwidth 166
 get_attribute 165
 get_properties_table 165
 get_synctex_fields 165
 has_attribute 166
 has_field 166
 has_glyph 166
 hpack 166
 hyphenating 166
 insert_after 166
 insert_before 166
 is_char 166
 is_direct 166
 is_glyph 166
 is_node 166
 is_zero_glue 166
 kerning 166
 last_node 166
 length 166
 ligaturing 166



new 166
prepend_prevdepth 166
protect_glyph 166
protect_glyphs 166
protrusion_skippable 166
rangedimensions 166
remove 166
setattributelist 167
setboth 167
setbox 167
setchar 167
setcomponents 167
setdata 167
setdepth 167
setdir 167
setdirection 167
setdisc 167
setexpansion 167
setfam 167
setfield 167
setfont 167
setglue 167
setheight 167
setkern 167
setlang 167
setleader 167
setlink 167
setlist 167
setnext 167
setnucleus 167
setoffsets 167
setpenalty 167
setprev 167
setproperty 167
setshift 167
setsplit 167
setsub 167
setsubtype 167
setsetup 167
setwhd 167
setwidth 167
set_attribute 166
set_properties_mode 166
set_synctex_fields 167
slide 167
tail 167

todirect 167
tonode 167
tostring 167
traverse 168
traverse_char 167
traverse_glyph 167
traverse_id 167
traverse_list 167
unprotect_glyph 168
unprotect_glyphs 168
unset_attribute 168
usedlist 168
uses_font 168
vpack 168
write 168

os

env 67
exec 67
gettimeofday 67
kpsepopen 67
name 67
selfdir 67
setenv 67
sleep 67
socketgettime 67
socketsleep 67
spawn 67
times 67
tmpdir 67
type 67
uname 67

pdf

getcatalog 285
getcompresslevel 286
getcreationdate 286
getdecimaldigits 287
getdestmargin 287
getfontname 287
getfontobjnum 287
getfontsize 287
getgentounicode 286
gethpos 287
getignoreunknownimages 286
getimageresolution 287
getinclusionerrorlevel 286
getinfo 285



getlastannot 287
 getlastlink 287
 getlastobj 287
 getlinkmargin 287
 getmajorversion 285
 getmarginmargin 287
 getmatrix 288
 getmaxobjnum 287
 getminorversion 285
 getnames 285
 getobjcompresslevel 286
 getobjtype 287
 getomitcharset 286
 getomitcidset 286
 getomitinfo 286
 getomitmediabox 286
 getomitprocset 286
 getorigin 287
 getpageattributes 285
 getpageref 290
 getpageresources 285
 getpagesattributes 285
 getpkresolution 287
 getpos 287
 getptexprefix 286
 getrecompress 286
 getretval 287
 getsuppressoptionalinfo 286
 getthreadmargin 287
 gettrailer 285
 gettrailerid 286
 getvpos 287
 getxformattributes 285
 getxformmargin 287
 getxformname 287
 getxformresources 285
 hasmatrix 288
 immediateobj 288
 newcolorstack 291
 obj 289
 print 288
 refobj 290
 registerannot 290
 reserveobj 290
 setcatalog 285
 setcompresslevel 286
 setdecimaldigits 287
 setdestmargin 287
 setfontattributes 291
 setgentounicode 286
 setignoreunknownimages 286
 setimageresolution 287
 setinclusionerrorlevel 286
 setinfo 285
 setlastannot 287
 setlastlink 287
 setlastobj 287
 setlinkmargin 287
 setmajorversion 285
 setmarginmargin 287
 setminorversion 285
 setnames 285
 setobjcompresslevel 286
 setomitcharset 286
 setomitcidset 286
 setomitinfo 286
 setomitmediabox 286
 setomitprocset 286
 setorigin 287
 setpageattributes 285
 setpageresources 285
 setpagesattributes 285
 setpkresolution 287
 setptexprefix 286
 setrecompress 286
 setsuppressoptionalinfo 286
 setthreadmargin 287
 settrailer 285
 settrailerid 286
 setxformattributes 285
 setxformmargin 287
 setxformresources 285

pdf

arraytotable 294
 close 291
 closestream 294
 dictionarytotable 294
 getarray 293
 getboolean 293
 getbox 292
 getcatalog 292
 getdictionary 293



- getfromarray 293, 294
- getfromdictionary 293, 294
- getfromreference 295
- getfromstream 293
- getinfo 292
- getinteger 293
- getmemoryusage 292
- getname 293
- getnofobjects 292
- getnofpages 292
- getnumber 293
- getpage 292
- getsize 292
- getstatus 291
- getstream 293
- getstring 293
- gettrailer 292
- getversion 292
- new 291, 295
- open 291
- openstream 294
- readfromstream 294
- readfromwholestream 294
- type 293
- unencrypt 291
- pdfscanner**
 - done 298
 - pop 298
 - poparray 298
 - popboolean 298
 - popdictionary 298
 - popname 298
 - popnumber 298
 - popstring 298
 - scan 295
- sha2**
 - digest256 69
 - digest384 69
 - digest512 69
- sio**
 - getposition 69
 - readbytes 69
 - readbytetable 69
 - readcardinaltable 69
 - readcardinal1 69
 - readcardinal2 69
 - readcardinal3 69
 - readcardinal4 69
 - readfixed2 69
 - readfixed4 69
 - readintegertable 69
 - readinteger1 69
 - readinteger2 69
 - readinteger3 69
 - readinteger4 69
 - read2dot14 69
 - setposition 69
 - skipposition 69
- status**
 - list 192
 - resetmessages 192
 - setexitcode 192
- string**
 - bytepairs 66
 - bytes 66
 - characterpairs 66
 - characters 66
 - explode 66
 - utfcharacter 67
 - utfcharacters 66
 - utflength 67
 - utfvalue 67
 - utfvalues 66
- tex**
 - attribute 198
 - badness 214
 - box 198, 201
 - catcode 200
 - count 198
 - cprint 207
 - definefont 210
 - delcode 200
 - dimen 198
 - enableprimitives 210
 - error 208
 - extraprimitives 211
 - finish 209
 - fontidentifier 208
 - fontname 208
 - forcehmode 209
 - force_synctex_line 216
 - force_synctex_tag 216



get 194
 getattribute 198
 getbox 198, 201
 getboxresourcedimensions 202
 getcatcode 200
 getcount 198
 getdelcode 200
 getdelcodes 200
 getdimen 198
 getglue 198
 getlccode 200
 getlist 204
 getlocallevel 216
 getmark 198
 getmath 203
 getmathcode 200
 getmathcodes 200
 getmuglue 198
 getmuskip 198
 getnest 204
 getpagestate 216
 getsfcode 200
 getskip 198
 gettoks 198
 getuccode 200
 get_synctex_line 216
 get_synctex_mode 216
 get_synctex_tag 216
 glue 198
 hashtokens 209
 init_rand 216
 isattribute 198
 isbox 198
 iscount 198
 isdimen 198
 isglue 198
 ismuglue 198
 ismuskip 198
 isskip 198
 istoks 198
 lccode 200
 linebreak 214
 lists 204
 lua_math_random 216
 lua_math_randomseed 216
 mathcode 200
 muglue 198
 muskip 198
 nest 204
 normal_rand 216
 number 208
 primitives 214
 print 205
 ptr 204
 resetparagraph 214
 romannumeral 208
 round 207
 run 209
 saveboxresource 202
 scale 207
 scantoks 198
 set 194
 setattribute 198
 setbox 198, 201
 setcatcode 200
 setcount 198
 setdelcode 200
 setdelcodes 200
 setdimen 198
 setglue 198
 setlccode 200
 setlist 204
 setmath 203
 setmathcode 200
 setmathcodes 200
 setmuglue 198
 setmuskip 198
 setsfcode 200
 setskip 198
 settoks 198
 setuccode 200
 set_synctex_line 216
 set_synctex_mode 216
 set_synctex_no_files 216
 set_synctex_tag 216
 sfcode 200
 shipout 216
 show_context 208
 skip 198
 sp 208
 splitbox 202
 sprint 205



toks 198
tprint 206
triggerbuildpage 202
uccode 200
uniformdeviate 216
uniform_rand 216
useboxresource 202
write 207

texio
closeinput 219
setescape 219
write 219
write_nl 219

token
biggest_char 222
commands 222
command_id 222
create 222
expand 222
get_active 222
get_cmdname 222
get_command 222
get_csname 222
get_expandable 222
get_functions_table 223
get_id 222
get_index 222
get_macro 223
get_meaning 223
get_mode 222
get_next 222, 224
get_protected 222
get_tok 222
is_defined 222
is_token 222
new 222
put_next 224
scan_argument 219
scan_code 219
scan_csname 219
scan_dimen 219
scan_float 219
scan_glue 219
scan_int 219
scan_keyword 219
scan_keywordcs 219
scan_list 219
scan_real 219
scan_string 219
scan_token 222
scan_toks 219
scan_word 219
set_char 223
set_lua 223
set_macro 223
unchecked_put_next 224



Statistics

The following fonts are used in this document:

| used | filesize | version | filename |
|-------------|------------------|----------------|----------------------------|
| 24 | 348.296 | 1.802 | LucidaBrightMath0T.otf |
| 4 | 73.284 | 1.801 | LucidaBright0T.otf |
| 24 | 733.736 | 1.959 | latinmodern-math.otf |
| 1 | 64.684 | 2.004 | lmmono10-regular.otf |
| 1 | 64.160 | 2.004 | lmmonoltcond10-regular.otf |
| 4 | 111.536 | 2.004 | lmroman10-regular.otf |
| 30 | 525.008 | 1.106 | texgyrejavu-math.otf |
| 24 | 601.220 | 1.632 | texgyrepagella-math.otf |
| 4 | 218.100 | 2.501 | texgyrepagella-regular.otf |
| 4 | 1.405.752 | 5.970 | Cambria.ttf |
| 24 | 1.408.700 | 5.960 | CambriaMath.ttf |
| 1 | 693.876 | 2.340 | DejaVuSans-Bold.ttf |
| 1 | 741.536 | 2.340 | DejaVuSans.ttf |
| 4 | 318.392 | 2.340 | DejaVuSansMono-Bold.ttf |
| 1 | 245.948 | 2.340 | DejaVuSansMono-Oblique.ttf |
| 3 | 335.068 | 2.340 | DejaVuSansMono.ttf |
| 9 | 345.364 | 2.340 | DejaVuSerif-Bold.ttf |
| 1 | 336.884 | 2.340 | DejaVuSerif-BoldItalic.ttf |
| 1 | 343.388 | 2.340 | DejaVuSerif-Italic.ttf |
| 5 | 367.260 | 2.340 | DejaVuSerif.ttf |
| 170 | 9.282.192 | | 20 files loaded |



