The luakeys package

Josef Friedrich
josef@friedrich.rocks
github.com/Josef-Friedrich/luakeys

v0.15.0 from 2024/09/29

```
local result = luakeys.parse(
  'level1={level2={naked,dim=1cm,bool=false,num=-0.001,str="lua,{}"}}',
  { convert_dimensions = true })
luakeys.debug(result)
```

Result:

```
{
  ['level1'] = {
    ['level2'] = {
      ['naked'] = true,
      ['dim'] = 1864679,
      ['bool'] = false,
      ['num'] = -0.001,
      ['str'] = 'lua,{}',
    }
  }
}
```

Contents

1 Introduction

`luakeys` is a Lua module / LuaTeX package that can parse key-value options like the TeX packages keyval, kvsetkeys, kvoptions, xkeyval, pgfkeys etc. `luakeys`, however, accomplishes this task by using the Lua language and doesn't rely on TeX. Therefore this package can only be used with the TeX engine LuaTeX. Since `luakeys` uses LPeg, the parsing mechanism should be pretty robust.

The TUGboat article "Implementing key–value input: An introduction" (Volume 30 (2009), No. 1) by *Joseph Wright* and *Christian Feuersänger* gives a good overview of the available key-value packages. This article is based on a question asked on tex.stackexchange.com by Will Robertson: A big list of every keyval package. CTAN also provides an overview page on the subject of Key-Val: packages with key-value argument systems.

This package would not be possible without the article "Parsing complex data formats in LuaTEX with LPEG" (Volume 40 (2019), No. 2).

1.1 Pros of `luakeys`

- Key-value pairs can be parsed independently of the macro collection (LaTeX or ConTeXt). Even in plain LuaTeX keys can be parsed.
- `luakeys` can handle nested lists of key-value pairs, i.e. it can handle a recursive data structure of keys.
- Keys do not have to be defined, but can they can be defined.

1.2 Cons of `luakeys`

- The package works only in combination with LuaTeX.
- You need to know two languages: TeX and Lua.

2 How the package is loaded

2.1 Using the Lua module `luakeys.lua`

The core functionality of this package is realized in Lua. So you can use `luakeys` even without using the wrapper files `luakeys.sty` and `luakeys.tex`.

```
\documentclass{article}
\directlua{
  lk = require('luakeys')()
}
\newcommand{\helloworld}[2][]{
  \directlua{
    local keys = lk.parse('\luaescapestring{\unexpanded{#1}}')
    lk.debug(keys)
    local marg = '#2'
    tex.print(keys.greeting .. ', ' .. marg .. keys.punctuation)
  }
}
\begin{document}
\helloworld[greeting=hello,punctuation=!]{world} % hello, world!
\end{document}
```

2.2 Using the LuaLaTeX wrapper `luakeys.sty`

For example, the MiKTeX package manager downloads packages only when needed. It has been reported that this automatic download only works with this wrapper files. Probably MiKTeX is searching for an occurrence of the LaTeX macro "`\usepackage{luakeys}`". The `luakeys.sty` file loads the Lua module into the global variable `luakeys`.

```
\documentclass{article}
\usepackage{luakeys}
\begin{document}
  \directlua{
    local lk = luakeys.new()
    local keys = lk.parse('one,two,three', { naked_as_value = true })
    tex.print(keys[1])
    tex.print(keys[2])
    tex.print(keys[3])
  } % one two three
\end{document}
```

2.3 Using the plain LuaTeX wrapper `luakeys.tex`

The file `luakeys.tex` does the same as the LuaLaTeX wrapper and loads the Lua module `luakeys.lua` into the global variable `luakeys`.

```
\input luakeys.tex
\directlua{
  local lk = luakeys.new()
  local keys = lk.parse('one,two,three', { naked_as_value = true })
  tex.print(keys[1])
  tex.print(keys[2])
  tex.print(keys[3])
} % one two three
\bye
```

3 Lua interface / API

Luakeys exports only one function that must be called to access the public API. This export function returns a table containing the public functions and additional tables:

```
local luakeys = require('luakeys')()
local new = luakeys.new
local version = luakeys.version
local parse = luakeys.parse
local define = luakeys.define
local opts = luakeys.opts
local error_messages = luakeys.error_messages
local render = luakeys.render
local stringify = luakeys.stringify
local debug = luakeys.debug
local save = luakeys.save
local get = luakeys.get
local is = luakeys.is
local utils = luakeys.utils
```

The project uses a few abbreviations for variable names that are hopefully unambiguous and familiar to external readers.

Abbreviation	spelled out	Example
`kv_string`	Key-value string	`'key=value'`
`opts`	Options (for the parse function)	`{ no_error = false }`
`defs`	Definitions	
`def`	Definition	
`attr`	Attributes (of a definition)	

These unabbreviated variable names are commonly used.

`result`	The final result of all individual parsing and normalization steps.
`unknown`	A table with unknown, undefinied key-value pairs.
`raw`	The raw result of the Lpeg grammar parser.

It is recommended to use luakeys together with the github.com/sumneko/lua-language-server when developing in a text editor. luakeys supports the annotation format offered by the server. You should then get warnings if you misuse luakeys' now rather large API.

3.1 Function "`parse(kv_string, opts): result, unknown, raw`"

The function `parse(kv_string, opts)` is the most important function of the package. It converts a key-value string into a Lua table.

```
\documentclass{article}
\usepackage{luakeys}
\begin{document}
\newcommand{\mykeyvalcmd}[2][]{
  \directlua{
    local lk = luakeys.new()
    local result = lk.parse('#1')
    tex.print('The key "one" has the value ' .. tostring(result.one) .. '.')
  }
  marg: #2
}
\mykeyvalcmd[one=1]{test}
\end{document}
```

In plain TeX:

```
\input luakeys.tex
\def\mykeyvalcmd#1{
  \directlua{
    local lk = luakeys.new()
    local result = lk.parse('#1')
    tex.print('The key "one" has the value ' .. tostring(result.one) .. '.')
  }
}
\mykeyvalcmd{one=1}
\bye
```

3.2 Options to configure the `parse` function

The `parse` function can be called with an options table. This options are supported: accumulated_result, assignment_operator, convert_dimensions, debug, default, defaults, defs, false_aliases, format_keys, group_begin, group_end, hooks, invert_flag, list_separator, naked_as_value, no_error, quotation_begin, quotation_end, true_aliases, unpack

```
local opts = {
  -- Result table that is filled with each call of the parse function.
  accumulated_result = accumulated_result,

  -- Configure the delimiter that assigns a value to a key.
  assignment_operator = '=',

  -- Automatically convert dimensions into scaled points (1cm -> 1864679).
  convert_dimensions = false,

  -- Print the result table to the console.
  debug = false,

  -- The default value for naked keys (keys without a value).
  default = true,

  -- A table with some default values. The result table is merged with
  -- this table.
  defaults = { key = 'value' },

  -- Key-value pair definitions.
  defs = { key = { default = 'value' } },

  -- Specify the strings that are recognized as boolean false values.
  false_aliases = { 'false', 'FALSE', 'False' },

  -- lower, snake, upper
  format_keys = { 'snake' },

  -- Configure the delimiter that marks the beginning of a group.
  group_begin = '{',

  -- Configure the delimiter that marks the end of a group.
  group_end = '}',

  -- Listed in the order of execution
  hooks = {
    kv_string = function(kv_string)
      return kv_string
    end,

    -- Visit all key-value pairs recursively.
    keys_before_opts = function(key, value, depth, current, result)
      return key, value
    end,

    -- Visit the result table.
    result_before_opts = function(result)
    end,

    -- Visit all key-value pairs recursively.
    keys_before_def = function(key, value, depth, current, result)
      return key, value
    end,

    -- Visit the result table.
    result_before_def = function(result)
    end,

    -- Visit all key-value pairs recursively.
    keys = function(key, value, depth, current, result)
      return key, value
    end,

    -- Visit the result table.
    result = function(result)
    end,
  },

  invert_flag = '!',

  -- Configure the delimiter that separates list items from each other.
  list_separator = ',',

  -- If true, naked keys are converted to values:
  -- { one = true, two = true, three = true } -> { 'one', 'two', 'three' }
  naked_as_value = false,

  -- Throw no error if there are unknown keys.
  no_error = false,

  -- Configure the delimiter that marks the beginning of a string.
  quotation_begin = '"',

  -- Configure the delimiter that marks the end of a string.
  quotation_end = '"',

  -- Specify the strings that are recognized as boolean true values.
  true_aliases = { 'true', 'TRUE', 'True' },

  -- { key = { 'value' } } -> { key = 'value' }
  unpack = false,
}
```

3.3 Table “opts”

The options can also be set globally using the exported table `opts`:

```
local result = luakeys.parse('dim=1cm') -- { dim = '1cm' }
```

```
luakeys.opts.convert_dimensions = true
local result2 = luakeys.parse('dim=1cm') -- { dim = 1234567 }
```

To avoid interactions with other packages that also use `luakeys` and set the options globally, it is recommended to use the `get_private_instance()` function (??) to load the package.

3.3.1 Option “`accumulated_result`”

Strictly speaking, this is not an option. The `accumulated_result` “option” can be used to specify a result table that is filled with each call of the `parse` function.

```
  local result = {}

  luakeys.parse('key1=one', { accumulated_result = result })
  assert.are.same({ key1 = 'one' }, result)

  luakeys.parse('key2=two', { accumulated_result = result })
  assert.are.same({ key1 = 'one', key2 = 'two' }, result)

  luakeys.parse('key1=1', { accumulated_result = result })
  assert.are.same({ key1 = 1, key2 = 'two' }, result)
```

3.3.2 Option “`assignment_operator`”

The option `assignment_operator` configures the delimiter that assigns a value to a key. The default value of this option is `"="`.

The code example below demonstrates all six delimiter related options.

```
local result = luakeys.parse(
  'level1: ( key1: value1; key2: "A string;" )', {
    assignment_operator = ':',
    group_begin = '(',
    group_end = ')',
    list_separator = ';',
    quotation_begin = '"',
    quotation_end = '"',
  })
luakeys.debug(result) -- { level1 = { key1 = 'value1', key2 = 'A string;' } }
```

Delimiter options	**Section**
assignment_operator	3.3.2
group_begin	3.3.10
group_end	3.3.11
list_separator	3.3.14
quotation_begin	3.3.17
quotation_end	3.3.18

3.3.3 Option “`convert_dimensions`”

If you set the option `convert_dimensions` to `true`, `luakeys` detects the TEX dimensions and converts them into scaled points using the function `tex.sp(dim)`.

```
local result = luakeys.parse('dim=1cm', {
  convert_dimensions = true,
})
-- result = { dim = 1864679 }
```

By default the dimensions are not converted into scaled points.

```
local result = luakeys.parse('dim=1cm', {
  convert_dimensions = false,
})
-- or
result = luakeys.parse('dim=1cm')
-- result = { dim = '1cm' }
```

If you want to convert a scaled points number into a dimension string you can use the module lualibs-util-dim.lua.

```
require('lualibs')
tex.print(number.todimen(tex.sp('1cm'), 'cm', '%0.0F%s'))
```

The default value of the option “`convert_dimensions`” is: `false`.

3.3.4 Option “`debug`”

If the option `debug` is set to true, the result table is printed to the console.

```
\documentclass{article}
\usepackage{luakeys}
\begin{document}
\directlua{
  lk = luakeys.new()
  lk.parse('one,two,three', { debug = true })
}
Lorem ipsum
\end{document}
```

```
This is LuaHBTeX, Version 1.15.0 (TeX Live 2022)
...
(./debug.aux) (/usr/local/texlive/texmf-dist/tex/latex/base/ts1cmr.fd)
{
  ['three'] = true,
  ['two'] = true,
  ['one'] = true,
}
 [1{/usr/
local/texlive/2022/texmf-var/fonts/map/pdftex/updmap/pdftex.map}] (./debug.aux)
)
...
Transcript written on debug.log.
```

The default value of the option “`debug`” is: `false`.

3.3.5 Option “`default`”

The option `default` can be used to specify which value naked keys (keys without a value) get. This option has no influence on keys with values.

```
local result = luakeys.parse('naked', { default = 1 })
luakeys.debug(result) -- { naked = 1 }
```

By default, naked keys get the value `true`.

```
local result2 = luakeys.parse('naked')
luakeys.debug(result2) -- { naked = true }
```

The default value of the option “`default`” is: `true`.

3.3.6 Option “`defaults`”

The option “defaults” can be used to specify not only one default value, but a whole table of default values. The result table is merged into the defaults table. Values in the defaults table are overwritten by values in the result table.

```
local result = luakeys.parse('key1=new', {
  defaults = { key1 = 'default', key2 = 'default' },
})
luakeys.debug(result) -- { key1 = 'new', key2 = 'default' }
```

The default value of the option “`defaults`” is: `false`.

3.3.7 Option “`defs`”

For more informations on how keys are defined, see section 3.4. If you use the `defs` option, you don’t need to call the `define` function. Instead of ...

```
local parse = luakeys.define({ one = { default = 1 }, two = { default = 2 } })
local result = parse('one,two') -- { one = 1, two = 2 }
```

we can write ...

```
local result2 = luakeys.parse('one,two', {
  defs = { one = { default = 1 }, two = { default = 2 } },
}) -- { one = 1, two = 2 }
```

The default value of the option “`defs`” is: `false`.

3.3.8 Option “`false_aliases`”

The `true_aliases` and `false_aliases` options can be used to specify the strings that will be recognized as boolean values by the parser. The following strings are configured by default.

```lua
local result = luakeys.parse('key=yes', {
  true_aliases = { 'true', 'TRUE', 'True' },
  false_aliases = { 'false', 'FALSE', 'False' },
})
luakeys.debug(result) -- { key = 'yes' }
```

```lua
local result2 = luakeys.parse('key=yes', {
  true_aliases = { 'on', 'yes' },
  false_aliases = { 'off', 'no' },
})
luakeys.debug(result2) -- { key = true }
```

```lua
local result3 = luakeys.parse('key=true', {
  true_aliases = { 'on', 'yes' },
  false_aliases = { 'off', 'no' },
})
luakeys.debug(result3) -- { key = 'true' }
```

See section 3.3.19 for the corresponding option.

3.3.9 Option “`format_keys`”

With the help of the option `format_keys` the keys can be formatted. The values of this option must be specified in a table.

lower To convert all keys to *lowercase*, specify `lower` in the options table.

```lua
local result = luakeys.parse('KEY=value', { format_keys = { 'lower' } })
luakeys.debug(result) -- { key = 'value' }
```

snake To make all keys *snake case* (The words are separated by underscores), specify `snake` in the options table.

```lua
local result2 = luakeys.parse('snake case=value', { format_keys = { 'snake'
↪  } })
luakeys.debug(result2) -- { snake_case = 'value' }
```

upper To convert all keys to *uppercase*, specify `upper` in the options table.

```
local result3 = luakeys.parse('key=value', { format_keys = { 'upper' } })
luakeys.debug(result3) -- { KEY = 'value' }
```

You can also combine several types of formatting.

```
local result4 = luakeys.parse('Snake Case=value', { format_keys = { 'lower',
↪  'snake' } })
luakeys.debug(result4) -- { snake_case = 'value' }
```

The default value of the option “`format_keys`” is: `false`.

3.3.10 Option “group_begin”

The option `group_begin` configures the delimiter that marks the beginning of a group. The default value of this option is `"{"`. A code example can be found in section 3.3.2.

3.3.11 Option “group_end”

The option `group_end` configures the delimiter that marks the end of a group. The default value of this option is `"}"`. A code example can be found in section 3.3.2.

3.3.12 Option “invert_flag”

If a naked key is prefixed with an exclamation mark, its default value is inverted. Instead of `true` the key now takes the value `false`.

```
local result = luakeys.parse('naked1,!naked2')
luakeys.debug(result) -- { naked1 = true, naked2 = false }
```

The `invert_flag` option can be used to change this inversion character.

```
local result2 = luakeys.parse('naked1,~naked2', { invert_flag = '~' })
luakeys.debug(result2) -- { naked1 = true, naked2 = false }
```

For example, if the default value for naked keys is set to `false`, the naked keys prefixed with the invert flat take the value `true`.

```
local result3 = luakeys.parse('naked1,!naked2', { default = false })
luakeys.debug(result3) -- { naked1 = false, naked2 = true }
```

Set the `invert_flag` option to `false` to disable this automatic boolean value inversion.

```
local result4 = luakeys.parse('naked1,!naked2', { invert_flag = false })
luakeys.debug(result4) -- { naked1 = true, ['!naked2'] = true }
```

3.3.13 Option “`hooks`”

The following hooks or callback functions allow to intervene in the processing of the `parse` function. The functions are listed in processing order. `*_before_opts` means that the hooks are executed after the LPeg syntax analysis and before the options are applied. The `*_before_defs` hooks are executed before applying the key value definitions.

1. `kv_string` `= function(kv_string): kv_string`
2. `keys_before_opts` `= function(key, value, depth, current, result): key, value`
3. `result_before_opts` `= function(result): void`
4. `keys_before_def` `= function(key, value, depth, current, result): key, value`
5. `result_before_def` `= function(result): void`
6. (`process`) (has to be definied using defs, see 3.5.13)
7. `keys` `= function(key, value, depth, current, result): key, value`
8. `result` `= function(result): void`

`kv_string` The `kv_string` hook is called as the first of the hook functions before the LPeg syntax parser is executed.

```
local result = luakeys.parse('key=unknown', {
  hooks = {
    kv_string = function(kv_string)
      return kv_string:gsub('unknown', 'value')
    end,
  },
})
luakeys.debug(result) -- { key = 'value' }
```

`keys_*` The hooks `keys_*` are called recursively on each key in the current result table. The hook function must return two values: `key, value`. The following example returns `key` and `value` unchanged, so the result table is not changed.

```
local result = luakeys.parse('l1={l2=1}', {
  hooks = {
    keys = function(key, value)
      return key, value
    end,
  },
})
luakeys.debug(result) -- { l1 = { l2 = 1 } }
```

The next example demonstrates the third parameter `depth` of the hook function.

```
local result = luakeys.parse('x,d1={x,d2={x}}', {
  naked_as_value = true,
  unpack = false,
  hooks = {
    keys = function(key, value, depth)
      if value == 'x' then
        return key, depth
      end
      return key, value
    end,
  },
})
luakeys.debug(result) -- { 1, d1 = { 2, d2 = { 3 } } }
```

`result_*` The hooks `result_*` are called once with the current result table as a parameter.

3.3.14 Option “`list_separator`”

The option `list_separator` configures the delimiter that separates list items from each other. The default value of this option is `","`. A code example can be found in section 3.3.2.

3.3.15 Option “`naked_as_value`”

With the help of the option `naked_as_value`, naked keys are not given a default value, but are stored as values in a Lua table.

```
local result = luakeys.parse('one,two,three')
luakeys.debug(result) -- { one = true, two = true, three = true }
```

If we set the option `naked_as_value` to `true`:

```
local result2 = luakeys.parse('one,two,three', { naked_as_value = true })
luakeys.debug(result2)
-- { [1] = 'one', [2] = 'two', [3] = 'three' }
-- { 'one', 'two', 'three' }
```

The default value of the option “`naked_as_value`” is: `false`.

3.3.16 Option “`no_error`”

By default the parse function throws an error if there are unknown keys. This can be prevented with the help of the `no_error` option.

```
  luakeys.parse('unknown', { defs = { 'key' } })
  -- Error message: Unknown keys: unknown,
```

If we set the option `no_error` to `true`:

```lua
luakeys.parse('unknown', { defs = { 'key' }, no_error = true })
-- No error message
```

The default value of the option “`no_error`” is: `false`.

3.3.17 Option “`quotation_begin`”

The option `quotation_begin` configures the delimiter that marks the beginning of a string. The default value of this option is `'"'` (double quotes). A code example can be found in section 3.3.2.

3.3.18 Option “`quotation_end`”

The option `quotation_end` configures the delimiter that marks the end of a string. The default value of this option is `'"'` (double quotes). A code example can be found in section 3.3.2.

3.3.19 Option “`true_aliases`”

See section 3.3.8.

3.3.20 Option “`unpack`”

With the help of the option `unpack`, all tables that consist of only a single naked key or a single standalone value are unpacked.

```lua
local result = luakeys.parse('key={string}', { unpack = true })
luakeys.debug(result) -- { key = 'string' }
```

```lua
local result2 = luakeys.parse('key={string}', { unpack = false })
luakeys.debug(result2) -- { key = { string = true } }
```

The default value of the option “`unpack`” is: `true`.

3.4 Function “`define(defs, opts): parse`”

The `define` function returns a `parse` function (see 3.1). The name of a key can be specified in three ways:

1. as a string.
2. as a key in a Lua table. The definition of the corresponding key-value pair is then stored under this key.
3. by the “name” attribute.

```
-- standalone string values
local defs = { 'key' }

-- keys in a Lua table
local defs = { key = {} }

-- by the "name" attribute
local defs = { { name = 'key' } }

local parse = luakeys.define(defs)
local result, unknown = parse('key=value,unknown=unknown', { no_error = true })
luakeys.debug(result) -- { key = 'value' }
luakeys.debug(unknown) -- { unknown = 'unknown' }
```

For nested definitions, only the last two ways of specifying the key names can be used.

```
local parse2 = luakeys.define({
  level1 = {
    sub_keys = { level2 = { sub_keys = { key = { } } } },
  },
}, { no_error = true })
local result2, unknown2 = parse2('level1={level2={key=value,unknown=unknown}}')
luakeys.debug(result2) -- { level1 = { level2 = { key = 'value' } } }
luakeys.debug(unknown2) -- { level1 = { level2 = { unknown = 'unknown' } } }
```

3.5 Attributes to define a key-value pair

The definition of a key-value pair can be made with the help of various attributes. The name *“attribute”* for an option, a key, a property ... (to list just a few naming possibilities) to define keys, was deliberately chosen to distinguish them from the options of the `parse` function. These attributes are allowed: alias, always_present, choices, data_type, default, description, exclusive_group, l3_tl_set, macro, match, name, opposite_keys, pick, process, required, sub_keys. The code example below lists all the attributes that can be used to define key-value pairs.

```
---@type DefinitionCollection
local defs = {
  key = {
    -- Allow different key names.
    -- or a single string: alias = 'k'
    alias = { 'k', 'ke' },

    -- The key is always included in the result. If no default value is
    -- definied, true is taken as the value.
    always_present = false,

    -- Only values listed in the array table are allowed.
    choices = { 'one', 'two', 'three' },

    -- Possible data types:
    -- any, boolean, dimension, integer, number, string, list
    data_type = 'string',
    -- To provide a default value for each naked key individually.
    default = true,

    -- Can serve as a comment.
    description = 'Describe your key-value pair.',

    -- The key belongs to a mutually exclusive group of keys.
    exclusive_group = 'name',

    -- > \MacroName
    macro = 'MacroName', -- > \MacroName

    -- See http://www.lua.org/manual/5.3/manual.html#6.4.1
    match = '^%d%d%d%d%-%d%d%-%d%d$',

    -- The name of the key, can be omitted
    name = 'key',

    -- Convert opposite (naked) keys
    -- into a boolean value and store this boolean under a target key:
    --   show -> opposite_keys = true
    --   hide -> opposite_keys = false
    -- Short form: opposite_keys = { 'show', 'hide' }
    opposite_keys = { [true] = 'show', [false] = 'hide' },

    -- Pick a value by its data type:
    -- 'any', 'string', 'number', 'dimension', 'integer', 'boolean'.
    pick = false, -- ’false’ disables the picking.

    -- A function whose return value is passed to the key.
    process = function(value, input, result, unknown)
      return value
    end,

    -- To enforce that a key must be specified.
    required = false,

    -- To build nested key-value pair definitions.
    sub_keys = { key_level_2 = { } },
  }
```

3.5.1 Attribute “alias”

With the help of the `alias` attribute, other key names can be used. The value is always stored under the original key name. A single alias name can be specified by a string ...

```
-- a single alias
local parse = luakeys.define({ key = { alias = 'k' } })
local result = parse('k=value')
luakeys.debug(result) -- { key = 'value' }
```

multiple aliases by a list of strings.

```
-- multiple aliases
local parse = luakeys.define({ key = { alias = { 'k', 'ke' } } })
local result = parse('ke=value')
luakeys.debug(result) -- { key = 'value' }
```

3.5.2 Attribute “always_present”

The `default` attribute is used only for naked keys.

```
local parse = luakeys.define({ key = { default = 1 } })
local result = parse('') -- { }
```

If the attribute `always_present` is set to true, the key is always included in the result. If no default value is definied, true is taken as the value.

```
local parse = luakeys.define({ key = { default = 1, always_present = true } })
local result = parse('') -- { key =  1 }
```

3.5.3 Attribute “choices”

Some key values should be selected from a restricted set of choices. These can be handled by passing an array table containing choices.

```
local parse = luakeys.define({ key = { choices = { 'one', 'two', 'three' } } })
local result = parse('key=one') -- { key = 'one' }
```

When the key-value pair is parsed, values will be checked, and an error message will be displayed if the value was not one of the acceptable choices:

```
    parse('key=unknown')
    -- error message:
    --- 'luakeys error [E004]: The value "unknown" does not exist in the choices:
    ↪  "one, two, three"'
```

3.5.4 Attribute “data_type”

The `data_type` attribute allows type-checking and type conversions to be performed. The following data types are supported: `'boolean'`, `'dimension'`, `'integer'`, `'number'`, `'string'`, `'list'`. A type conversion can fail with the three data types `'dimension'`, `'integer'`, `'number'`. Then an error message is displayed.

```
local function assert_type(data_type, input_value, expected_value)
  assert.are.same({ key = expected_value },
    luakeys.parse('key=' .. tostring(input_value),
      { defs = { key = { data_type = data_type } } }))
end
```

```
  assert_type('boolean', 'true', true)
  assert_type('dimension', '1cm', '1cm')
  assert_type('integer', '1.23', 1)
  assert_type('number', '1.23', 1.23)
  assert_type('string', 1.23, '1.23')
```

3.5.5 Attribute “`default`”

Use the `default` attribute to provide a default value for each naked key individually. With the global `default` attribute (3.3.5) a default value can be specified for all naked keys.

```
local parse = luakeys.define({
  one = {},
  two = { default = 2 },
  three = { default = 3 },
}, { default = 1, defaults = { four = 4 } })
local result = parse('one,two,three') -- { one = 1, two = 2, three = 3, four = 4 }
```

3.5.6 Attribute “`description`”

This attribute is currently not processed further. It can serve as a comment.

3.5.7 Attribute “`exclusive_group`”

All keys belonging to the same exclusive group must not be specified together. Only one key from this group is allowed. Any value can be used as a name for this exclusive group.

```
local parse = luakeys.define({
  key1 = { exclusive_group = 'group' },
  key2 = { exclusive_group = 'group' },
})
local result1 = parse('key1') -- { key1 = true }
local result2 = parse('key2') -- { key2 = true }
```

If more than one key of the group is specified, an error message is thrown.

```
    parse('key1,key2') -- throws error message:
    -- 'The key "key2" belongs to a mutually exclusive group "group"
    -- and the key "key1" is already present!'
```

3.5.8 Attribute “`macro`”

The attribute `macro` stores the value in a TEX macro.

```
local parse = luakeys.define({
  key = {
    macro = 'MyMacro'
  }
})
parse('key=value')
```

```
\MyMacro % expands to "value"
```

3.5.9 Attribute “match”

The value of the key is first passed to the Lua function `string.match(value, match)` (http://www.lua.org/manual/5.3/manual.html#pdf-string.match) before being assigned to the key. You can therefore configure the `match` attribute with a pattern matching string used in Lua. Take a look at the Lua manual on how to write patterns (http://www.lua.org/manual/5.3/manual.html#6.4.1).

```
local parse = luakeys.define({
  birthday = { match = '^%d%d%d%d%-%d%d%-%d%d$' },
})
local result = parse('birthday=1978-12-03') -- { birthday = '1978-12-03' }
```

If the pattern cannot be found in the value, an error message is issued.

```
    parse('birthday=1978-12-XX')
    -- throws error message:
    -- 'luakeys error [E009]: The value "1978-12-XX" of the key "birthday"
    --  does not match "^%d%d%d%d%-%d%d%-%d%d$"!'
```

The key receives the result of the function `string.match(value, match)`, which means that the original value may not be stored completely in the key. In the next example, the entire input value is accepted:

```
local parse = luakeys.define({ year = { match = '%d%d%d%d' } })
local result = parse('year=1978') -- { year = '1978' }
```

The prefix “waste ” and the suffix “ rubbisch” of the string are discarded.

```
local result2 = parse('year=waste 1978 rubbisch') -- { year = '1978' }
```

Since function `string.match(value, match)` always returns a string, the value of the key is also always a string.

3.5.10 Attribute “name”

The `name` attribute allows an alternative notation of key names. Instead of ...

```
local parse1 = luakeys.define({
  one = { default = 1 },
  two = { default = 2 },
})
local result1 = parse1('one,two') -- { one = 1, two = 2 }
```

... we can write:

```
local parse = luakeys.define({
  { name = 'one', default = 1 },
  { name = 'two', default = 2 },
})
local result = parse('one,two') -- { one = 1, two = 2 }
```

3.5.11 Attribute "opposite_keys"

The `opposite_keys` attribute allows to convert opposite (naked) keys into a boolean value and store this boolean under a target key. Lua allows boolean values to be used as keys in tables. However, the boolean values must be written in square brackets, e. g. `opposite_keys = { [true] = 'show', [false] = 'hide' }`. Examples of opposing keys are: `show` and `hide`, `dark` and `light`, `question` and `solution`. The example below uses the `show` and `hide` keys as the opposite key pair. If the key `show` is parsed by the `parse` function, then the target key `visibility` receives the value `true`.

```
local parse = luakeys.define({
  visibility = { opposite_keys = { [true] = 'show', [false] = 'hide' } },
})
local result = parse('show') -- { visibility = true }
```

If the key `hide` is parsed, then `false`.

```
local result = parse('hide') -- { visibility = false }
```

Opposing key pairs can be specified in a short form, namely as a list: The opposite key, which represents the true value, must be specified first in this list, followed by the false value.

```
local parse = luakeys.define({
  visibility = { opposite_keys = { 'show', 'hide' } },
})
```

3.5.12 Attribute "pick"

The attribute `pick` searches for a value not assigned to a key. The first value found, i.e. the one further to the left, is assigned to a key.

```
local parse = luakeys.define({ font_size = { pick = 'dimension' } })
local result = parse('12pt,13pt', { no_error = true })
luakeys.debug(result) -- { font_size = '12pt' }
```

Only the current result table is searched, not other levels in the recursive data structure.

```
local parse = luakeys.define({
  level1 = {
    sub_keys = { level2 = { default = 2 }, key = { pick = 'boolean' } },
  },
}, { no_error = true })
local result, unknown = parse('true,level1={level2,true}')
luakeys.debug(result) -- { level1 = { key = true, level2 = 2 } }
luakeys.debug(unknown) -- { true }
```

The search for values is activated when the attribute `pick` is set to a data type. These data types can be used to search for values: string, number, dimension, integer, boolean, any. Use the data type "any" to accept any value. If a value is already assigned to a key when it is entered, then no further search for values is performed.

```
local parse = luakeys.define({ font_size = { pick = 'dimension' } })
local result, unknown =
  parse('font_size=11pt,12pt', { no_error = true })
luakeys.debug(result) -- { font_size = '11pt' }
luakeys.debug(unknown) -- { '12pt' }
```

The `pick` attribute also accepts multiple data types specified in a table.

```
local parse = luakeys.define({
  key = { pick = { 'number', 'dimension' } },
})
local result = parse('string,12pt,42', { no_error = true })
luakeys.debug(result) -- { key = 42 }
local result2 = parse('string,12pt', { no_error = true })
luakeys.debug(result2) -- { key = '12pt' }
```

3.5.13 Attribute "process"

The `process` attribute can be used to define a function whose return value is passed to the key. Four parameters are passed when the function is called:

1. `value`: The current value asssociated with the key.
2. `input`: The result table cloned before the time the definitions started to be applied.
3. `result`: The table in which the final result will be saved.
4. `unknown`: The table in which the unknown key-value pairs are stored.

The following example demonstrates the `value` parameter:

```lua
local parse = luakeys.define({
  key = {
    process = function(value, input, result, unknown)
      if type(value) == 'number' then
        return value + 1
      end
      return value
    end,
  },
})
local result = parse('key=1') -- { key = 2 }
```

The following example demonstrates the `input` parameter:

```lua
local parse = luakeys.define({
  'one',
  'two',
  key = {
    process = function(value, input, result, unknown)
      value = input.one + input.two
      result.one = nil
      result.two = nil
      return value
    end,
  },
})
local result = parse('key,one=1,two=2') -- { key = 3 }
```

The following example demonstrates the `result` parameter:

```lua
local parse = luakeys.define({
  key = {
    process = function(value, input, result, unknown)
      result.additional_key = true
      return value
    end,
  },
})
local result = parse('key=1') -- { key = 1, additional_key = true }
```

The following example demonstrates the `unknown` parameter:

```lua
local parse = luakeys.define({
  key = {
    process = function(value, input, result, unknown)
      unknown.unknown_key = true
      return value
    end,
  },
})
```

```lua
    parse('key=1') -- throws error message: 'luakeys error [E019]: Unknown keys:
    ↪  "unknown_key=true,"'
```

3.5.14 Attribute “`required`”

The `required` attribute can be used to enforce that a specific key must be specified. In the example below, the key `important` is defined as mandatory.

```
local parse = luakeys.define({ important = { required = true } })
local result = parse('important') -- { important = true }
```

If the key `important` is missing in the input, an error message occurs.

```
    parse('unimportant')
    -- throws error message: 'luakeys error [E012]: Missing required key
    ↪   "important"!'
```

A recursive example:

```
local parse2 = luakeys.define({
  important1 = {
    required = true,
    sub_keys = { important2 = { required = true } },
  },
})
```

The `important2` key on level 2 is missing.

```
      parse2('important1={unimportant}')
      -- throws error message: 'luakeys error [E012]: Missing required key
      ↪   "important2"!'
```

The `important1` key at the lowest key level is missing.

```
      parse2('unimportant')
      -- throws error message: 'luakeys error [E012]: Missing required key
      ↪   "important1"!'
```

3.5.15 Attribute “`sub_keys`”

The `sub_keys` attribute can be used to build nested key-value pair definitions.

```
local result, unknown = luakeys.parse('level1={level2,unknown}', {
  no_error = true,
  defs = {
    level1 = {
      sub_keys = {
        level2 = { default = 42 }
      }
    }
  },
})
luakeys.debug(result) -- { level1 = { level2 = 42 } }
luakeys.debug(unknown) -- { level1 = { 'unknown' } }
```

3.6 Function “`render(result): string`”

The function `render(result)` reverses the function `parse(kv_string)`. It takes a Lua table and converts this table into a key-value string. The resulting string usually has a different order as the input table.

```
local result = luakeys.parse('one=1,two=2,three=3,')
local kv_string = luakeys.render(result)
--- one=1,two=2,tree=3,
--- or:
--- two=2,one=1,tree=3,
--- or:
--- ...
```

In Lua only tables with 1-based consecutive integer keys (a.k.a. array tables) can be parsed in order.

```
local result2 = luakeys.parse('one,two,three', { naked_as_value = true })
local kv_string2 = luakeys.render(result2) --- one,two,three, (always)
```

3.7 Function “`debug(result): void`”

The function `debug(result)` pretty prints a Lua table to standard output (stdout). It is a utility function that can be used to debug and inspect the resulting Lua table of the function `parse`. You have to compile your TeX document in a console to see the terminal output.

```
local result = luakeys.parse('level1={level2={key=value}}')
luakeys.debug(result)
```

The output should look like this:

```
{
  ['level1'] = {
      ['level2'] = {
        ['key'] = 'value',
    },
  }
}
```

3.8 Function “`save(identifier, result): void`”

The function `save(identifier, result)` saves a result (a table from a previous run of `parse`) under an identifier. Therefore, it is not necessary to pollute the global namespace to store results for the later usage.

3.9 Function “`get(identifier): result`”

The function `get(identifier)` retrieves a saved result from the result store.

3.10 Class “`DefinitionManager()`”

The DefinitionManager class makes it possible to store key-value definitions in a central location. New subsets of definitions can be formed based on the saved definitions using the `include` and `exclude` methods.

```lua
local DefinitionManager = luakeys.DefinitionManager

local manager = DefinitionManager({
  key1 = { default = 1 },
  key2 = { default = 2 },
  key3 = { default = 3 },
})

local def = manager:get('key1')
luakeys.debug(def) -- { default = 1 }

local defs1 = manager:include({ 'key2' })
luakeys.debug(defs1) -- { key2 = { default = 2 } }

local defs2 = manager:exclude({ 'key2' })
luakeys.debug(defs2) -- { key1 = { default = 1 }, key3 = { default = 3 } }

manager:parse('key3', { 'key3' }) -- { key3 = 3 }
manager:parse('new3', { key3 = 'new3' }) -- { new3 = 3 }
--manager:parse('key1', { 'key3' }) -- 'Unknown keys: "key1,"'
```

3.11 Table “`is`”

In the table `is` some functions are summarized, which check whether an input corresponds to a certain data type. Some functions accept not only the corresponding Lua data types, but also input as strings. For example, the string `'true'` is recognized by the `is.boolean()` function as a boolean value.

3.11.1 Function “`is.boolean(value): boolean`”

```lua
  -- true
  equal(luakeys.is.boolean('true'), true) -- input: string!
  equal(luakeys.is.boolean('True'), true) -- input: string!
  equal(luakeys.is.boolean('TRUE'), true) -- input: string!
  equal(luakeys.is.boolean('false'), true) -- input: string!
  equal(luakeys.is.boolean('False'), true) -- input: string!
  equal(luakeys.is.boolean('FALSE'), true) -- input: string!
  equal(luakeys.is.boolean(true), true)
  equal(luakeys.is.boolean(false), true)
  -- false
  equal(luakeys.is.boolean('xxx'), false)
  equal(luakeys.is.boolean('trueX'), false)
  equal(luakeys.is.boolean('1'), false)
  equal(luakeys.is.boolean('0'), false)
  equal(luakeys.is.boolean(1), false)
  equal(luakeys.is.boolean(0), false)
  equal(luakeys.is.boolean(nil), false)
end)
```

3.11.2 Function “`is.dimension(value): boolean`”

```
  -- true
  equal(luakeys.is.dimension('1 cm'), true)
  equal(luakeys.is.dimension('- 1 mm'), true)
  equal(luakeys.is.dimension('-1.1pt'), true)
  -- false
  equal(luakeys.is.dimension('1cmX'), false)
  equal(luakeys.is.dimension('X1cm'), false)
  equal(luakeys.is.dimension(1), false)
  equal(luakeys.is.dimension('1'), false)
  equal(luakeys.is.dimension('xxx'), false)
  equal(luakeys.is.dimension(nil), false)
```

3.11.3 Function “`is.integer(value): boolean`”

```
  -- true
  equal(luakeys.is.integer('42'), true) -- input: string!
  equal(luakeys.is.integer(1), true)
  -- false
  equal(luakeys.is.integer('1.1'), false)
  equal(luakeys.is.integer('xxx'), false)
```

3.11.4 Function “`is.number(value): boolean`”

```
  -- true
  equal(luakeys.is.number('1'), true) -- input: string!
  equal(luakeys.is.number('1.1'), true) -- input: string!
  equal(luakeys.is.number(1), true)
  equal(luakeys.is.number(1.1), true)
  -- false
  equal(luakeys.is.number('xxx'), false)
  equal(luakeys.is.number('1cm'), false)
```

3.11.5 Function “`is.string(value): boolean`”

```
  -- true
  equal(luakeys.is.string('string'), true)
  equal(luakeys.is.string(''), true)
  -- false
  equal(luakeys.is.string(true), false)
```

```
equal(luakeys.is.string(1), false)
equal(luakeys.is.string(nil), false)
```

3.11.6 Function “`is.list(value): boolean`”

```
-- true
equal(luakeys.is.list({ 'one', 'two', 'three' }), true)
equal(luakeys.is.list({ [1] = 'one', [2] = 'two', [3] = 'three' }),
  true)

-- false
equal(luakeys.is.list({ one = 'one', two = 'two', three = 'three' }),
  false)
equal(luakeys.is.list('one,two,three'), false)
equal(luakeys.is.list('list'), false)
equal(luakeys.is.list(nil), false)
```

3.11.7 Function “`is.any(value): boolean`”

The function `is.any(value)` always returns `true` and therefore accepts any data type.

3.12 Table “`utils`”

The `utils` table bundles some auxiliary functions.

```
local utils = require('luakeys')().utils

---table
local merge_tables = utils.merge_tables
local clone_table = utils.clone_table
local remove_from_table = utils.remove_from_table
local get_table_keys = utils.get_table_keys
local get_table_size = utils.get_table_size
local get_array_size = utils.get_array_size

local tex_printf = utils.tex_printf

---error
local throw_error_message = utils.throw_error_message
local throw_error_code = utils.throw_error_code

---ansi_color
local colorize = utils.ansi_color.colorize
local red = utils.ansi_color.red
local green = utils.ansi_color.green
local yellow = utils.ansi_color.yellow
local blue = utils.ansi_color.blue
local magenta = utils.ansi_color.magenta
local cyan = utils.ansi_color.cyan

---log
local set = utils.log.set
local get = utils.log.set
local err = utils.log.error
local warn = utils.log.warn
local info = utils.log.info
local verbose = utils.log.verbose
local debug = utils.log.debug
```

3.12.1 Function "`utils.merge_tables(target, source, overwrite): table`"

The function `merge_tables` merges two tables into the first specified table. It copies keys from the ‘source‘ table into the ‘target‘ table. It returns the target table.

If the `overwrite` parameter is set to `true`, values in the target table are overwritten.

```
local result = luakeys.utils.merge_tables({ key = 'target' }, {
  key = 'source',
  key2 = 'new',
}, true)
luakeys.debug(result) -- { key = 'source', key2 = 'new' }
```

Give the parameter `overwrite` the value `false` to overwrite values in the target table.

```
local result2 = luakeys.utils.merge_tables({ key = 'target' }, {
  key = 'source',
  key2 = 'new',
}, false)
luakeys.debug(result2) -- { key = 'target', key2 = 'new' }
```

3.13 Table "version"

The luakeys project uses semantic versioning. The three version numbers of the semantic versioning scheme are stored in a table as integers in the order MAJOR, MINOR, PATCH. This table can be used to check whether the correct version is installed.

```
local v = luakeys.version
local version_string = v[1] .. '.' .. v[2] .. '.' .. v[3]
print(version_string) -- 0.7.0

if v[1] >= 1 and v[2] > 2 then
  print('You are using the right version.')
end
```

3.14 Table "error_messages"

```
local parse = luakeys.define({ key = { required = true } })

it('Default error', function()
  assert.has_error(function()
    parse('unknown')
  end, 'luakeys error [E012]: Missing required key "key"!')
end)

it('Custom error', function()
  luakeys.error_messages.E012 = 'The key @key is missing!'
  assert.has_error(function()
    parse('unknown')
  end, 'luakeys error [E012]: The key "key" is missing!')
end)
```

E001 : `Unknown parse option: @unknown!`

E002 : `Unknown hook: @unknown!`

E003 : `Duplicate aliases @alias1 and @alias2 for key @key!`

E004 : `The value @value does not exist in the choices: @choices`

E005 : `Unknown data type: @unknown`

E006 : `The value @value of the key @key could not be converted into the data type @data_type!`

E007 : `The key @key belongs to the mutually exclusive group @exclusive_group and another key of the group named @another_key is already present!`

E008 : `def.match has to be a string`

E009 : `The value @value of the key @key does not match @match!`

E010 : `Usage: opposite_keys = "true_key", "false_key" or [true] = "true_key", [false] = "false_key"`

E011 : `Wrong data type in the "pick" attribute: @unknown. Allowed are: @data_types.`

E012 : `Missing required key @key!`

E013 : `The key definition must be a table! Got @data_type for key @key.`

E014 : `Unknown definition attribute: @unknown`

E015 : `Key name couldn’t be detected!`

E017 : `Unknown style to format keys: @unknown! Allowed styles are: @styles`

E018 : `The option "format_keys" has to be a table not @data_type`

E019 : `Unknown keys: @unknown`

E020 : `Both opposite keys were given: @true and @false!`

E021 : `Opposite key was specified more than once: @key!`

E023 : `Don’t use this function from the global luakeys table. Create a new instance using e. g.: local lk = luakeys.new()`

4 Syntax of the recognized key-value format

4.1 An attempt to put the syntax into words

A key-value pair is definied by an equal sign (`key=value`). Several key-value pairs or keys without values (naked keys) are lined up with commas (`key=value,naked`) and build a key-value list. Curly brackets can be used to create a recursive data structure of nested key-value lists (`level1={level2={key=value,naked}}`).

4.2 An (incomplete) attempt to put the syntax into the Extended Backus-Naur Form

⟨*list*⟩ ::= { ⟨*list-item*⟩ }

⟨*list-container*⟩ ::= ‘`{`’ ⟨*list*⟩ ‘`}`’

⟨*list-item*⟩ ::= (⟨*list-container*⟩ | ⟨*key-value-pair*⟩ | ⟨*value*⟩) [‘`,`’]

⟨*key-value-pair*⟩ ::= ⟨*value*⟩ ‘`=`’ (⟨*list-container*⟩ | ⟨*value*⟩)

⟨*value*⟩ ::= ⟨*boolean*⟩
  | ⟨*dimension*⟩
  | ⟨*number*⟩
  | ⟨*string-quoted*⟩
  | ⟨*string-unquoted*⟩

⟨*dimension*⟩ ::= ⟨*number*⟩ ⟨*unit*⟩

⟨*number*⟩ ::= ⟨*sign*⟩ (⟨*integer*⟩ [⟨*fractional*⟩] | ⟨*fractional*⟩)

⟨*fractional*⟩ ::= ‘`.`’ ⟨*integer*⟩

⟨*sign*⟩ ::= ‘`-`’ | ‘`+`’

⟨*integer*⟩ ::= ⟨*digit*⟩ { ⟨*digit*⟩ }

⟨*digit*⟩ ::= ‘`0`’ | ‘`1`’ | ‘`2`’ | ‘`3`’ | ‘`4`’ | ‘`5`’ | ‘`6`’ | ‘`7`’ | ‘`8`’ | ‘`9`’

⟨*unit*⟩ ::= ‘`bp`’ | ‘`BP`’
  | ‘`cc`’ | ‘`CC`’
  | ‘`cm`’ | ‘`CM`’
  | ‘`dd`’ | ‘`DD`’
  | ‘`em`’ | ‘`EM`’
  | ‘`ex`’ | ‘`EX`’
  | ‘`in`’ | ‘`IN`’
  | ‘`mm`’ | ‘`MM`’
  | ‘`mu`’ | ‘`MU`’
  | ‘`nc`’ | ‘`NC`’
  | ‘`nd`’ | ‘`ND`’
  | ‘`pc`’ | ‘`PC`’
  | ‘`pt`’ | ‘`PT`’

| ‘`px`’ | ‘`PX`’
| ‘`sp`’ | ‘`SP`’

⟨*boolean*⟩ ::= ⟨*boolean-true*⟩ | ⟨*boolean-false*⟩

⟨*boolean-true*⟩ ::= ‘`true`’ | ‘`TRUE`’ | ‘`True`’

⟨*boolean-false*⟩ ::= ‘`false`’ | ‘`FALSE`’ | ‘`False`’

... to be continued

4.3 Recognized data types

4.3.1 boolean

The strings `true`, `TRUE` and `True` are converted into Lua’s boolean type `true`, the strings `false`, `FALSE` and `False` into `false`.

```
\luakeysdebug{
  lower case true = true,
  upper case true = TRUE,
  title case true = True,
  lower case false = false,
  upper case false = FALSE,
  title case false = False,
}
```

```
{
  ['lower case true'] = true,
  ['upper case true'] = true,
  ['title case true'] = true,
  ['lower case false'] = false,
  ['upper case false'] = false
  ['title case false'] = false,
}
```

4.3.2 number

```
\luakeysdebug{
  num0 = 042,
  num1 = 42,
  num2 = -42,
  num3 = 4.2,
  num4 = 0.42,
  num5 = .42,
  num6 = 0 . 42,
}
```

```
{
  ['num0'] = 42,
  ['num1'] = 42,
  ['num2'] = -42,
  ['num3'] = 4.2,
  ['num4'] = 0.42,
  ['num5'] = 0.42,
  ['num6'] = '0 . 42', -- string
}
```

4.3.3 dimension

`luakeys` tries to recognize all units used in the TEX world. According to the LuaTEX source code (source/texk/web2c/luatexdir/lua/ltexlib.c) and the dimension module of the lualibs library (lualibs-util-dim.lua), all units should be recognized.

	Description
bp	big point
cc	cicero
cm	centimeter
dd	didot
em	horizontal measure of M
ex	vertical measure of x
in	inch
mm	milimeter
mu	math unit
nc	new cicero
nd	new didot
pc	pica
pt	point
px	x height current font
sp	scaledpoint

```
\luakeysdebug[convert_dimensions=true]{
  bp = 1bp,
  cc = 1cc,
  cm = 1cm,
  dd = 1dd,
  em = 1em,
  ex = 1ex,
  in = 1in,
  mm = 1mm,
  mu = 1mu,
  nc = 1nc,
  nd = 1nd,
  pc = 1pc,
  pt = 1pt,
  px = 1px,
  sp = 1sp,
}
```

```
{
  ['bp'] = 65781,
  ['cc'] = 841489,
  ['cm'] = 1864679,
  ['dd'] = 70124,
  ['em'] = 655360,
  ['ex'] = 282460,
  ['in'] = 4736286,
  ['mm'] = 186467,
  ['mu'] = 65536,
  ['nc'] = 839105,
  ['nd'] = 69925,
  ['pc'] = 786432,
  ['pt'] = 65536,
  ['px'] = 65781,
  ['sp'] = 1,
}
```

The next example illustrates the different notations of the dimensions.

```
\luakeysdebug[convert_dimensions=true]{
  upper = 1CM,
  lower = 1cm,
  space = 1 cm,
  plus = + 1cm,
  minus = -1cm,
  nodim = 1 c m,
}
```

```
{
  ['upper'] = 1864679,
  ['lower'] = 1864679,
  ['space'] = 1864679,
  ['plus'] = 1864679,
  ['minus'] = -1864679,
  ['nodim'] = '1 c m', -- string
}
```

4.3.4 string

There are two ways to specify strings: With or without double quotes. If the text have to contain commas, curly braces or equal signs, then double quotes must be used.

```
local kv_string = [[
  without double quotes = no commas and equal signs are allowed,
  with double quotes = ", and = are allowed",
  escape quotes = "a quote \" sign",
  curly braces = "curly { } braces are allowed",
]]
local result = luakeys.parse(kv_string)
luakeys.debug(result)
-- {
--   ['without double quotes'] = 'no commas and equal signs are allowed',
--   ['with double quotes'] = ', and = are allowed',
--   ['escape quotes'] = 'a quote \" sign',
--   ['curly braces'] = 'curly { } braces are allowed',
-- }
```

4.3.5 Naked keys

Naked keys are keys without a value. Using the option `naked_as_value` they can be converted into values and stored into an array. In Lua an array is a table with numeric indexes (The first index is 1).

```
\luakeysdebug[naked_as_value=true]{one,two,three}
% {
%   [1] = 'one',
%   [2] = 'two',
%   [3] = 'three',
% }
% =
% { 'one', 'two', 'three' }
```

All recognized data types can be used as standalone values.

```
\luakeysdebug[naked_as_value=true]{one,2,3cm}
% {
%   [1] = 'one',
%   [2] = 2,
%   [3] = '3cm',
% }
```

5 Examples

5.1 Extend and modify keys of existing macros

Extend the includegraphics macro with a new key named `caption` and change the accepted values of the `width` key. A number between 0 and 1 is allowed and converted into `width=0.5\linewidth`

```lua
local luakeys = require('luakeys')()

local parse = luakeys.define({
  caption = { alias = 'title' },
  width = {
    process = function(value)
      if type(value) == 'number' and value >= 0 and value <= 1 then
        return tostring(value) .. '\\linewidth'
      end
      return value
    end,
  },
})

local function print_image_macro(image_path, kv_string)
  local caption = ''
  local options = ''
  local keys, unknown = parse(kv_string)
  if keys['caption'] ~= nil then
    caption = '\\ImageCaption{' .. keys['caption'] .. '}'
  end
  if keys['width'] ~= nil then
    unknown['width'] = keys['width']
  end
  options = luakeys.render(unknown)

  tex.print('\\includegraphics[' .. options .. ']{' .. image_path .. '}' ..
              caption)
end

return print_image_macro
```

```latex
\documentclass{article}
\usepackage{graphicx}
\begin{document}
\newcommand{\ImageCaption}[1]{%
  \par\textit{#1}%
}

\newcommand{\myincludegrahics}[2][]{
  \directlua{
    print_image_macro = require('extend-keys.lua')
    print_image_macro('#2', '#1')
  }
}

\myincludegrahics{test.png}

\myincludegrahics[width=0.5]{test.png}
```

```
\myincludegrahics[caption=A caption]{test.png}
\end{document}
```

5.2 Process document class options

The options of a LaTeX document class can be accessed via the `\LuakeysGetClassOptions` macro. `\LuakeysGetClassOptions` is an alias for

`\luaescapestring{\@raw@classoptionslist}`.

```
\NeedsTeXFormat{LaTeX2e}
\ProvidesClass{test-class}[2022/05/26 Test class to access the class options]
\DeclareOption*{} % suppresses the warning: LaTeX Warning: Unused global option(s):
\ProcessOptions\relax
\RequirePackage{luakeys}

\directlua{
  lk = luakeys.new()
}

% Using the macro \LuakeysGetClassOptions
\directlua{
  lk.debug(lk.parse('\LuakeysGetClassOptions'))
}

% Low level approach
\directlua{
  lk.debug(lk.parse('\luaescapestring{\@raw@classoptionslist}'))
}

\LoadClass{article}
```

```
\documentclass[test={key1,key2}]{test-class}

\begin{document}
This document uses the class "test-class".
\end{document}
```

5.3 Process package options

The options of a LaTeX package can be accessed via the `\LuakeysGetPackageOptions` macro. `\LuakeysGetPackageOptions` is an alias for

`\luaescapestring{\@ptionlist{\@currname.\@currext}}`.

```
\NeedsTeXFormat{LaTeX2e}
\ProvidesPackage{test-package}[2022/11/27 Test package to access the package
↪  options]
\DeclareOption*{} % suppresses the error message: ! LaTeX Error: Unknown option
```

```
\ProcessOptions\relax
\RequirePackage{luakeys}

\directlua{
  lk = luakeys.new()
}

% Using the macro \LuakeysGetPackageOptions
\directlua{
  lk.debug(lk.parse('\LuakeysGetPackageOptions'))
}

% Low level approach
\directlua{
  lk.debug(lk.parse('\luaescapestring{\@ptionlist{\@currname.\@currext}}'))
}
```

```
\documentclass{article}
\usepackage[test={key1,key2}]{test-package}
\begin{document}
This document uses the package "test-package".
\end{document}
```

6 Debug packages

Two small debug packages are included in `luakeys`. One debug package can be used in LaTeX (luakeys-debug.sty) and one can be used in plain TeX (luakeys-debug.tex). Both packages provide only one command: `\luakeysdebug{kv-string}`

```
\luakeysdebug{one,two,three}
```

Then the following output should appear in the document:

```
{
  ['one'] = true,
  ['two'] = true,
  ['three'] = true,
}
```

6.1 For plain TeX: luakeys-debug.tex

An example of how to use the command in plain TeX:

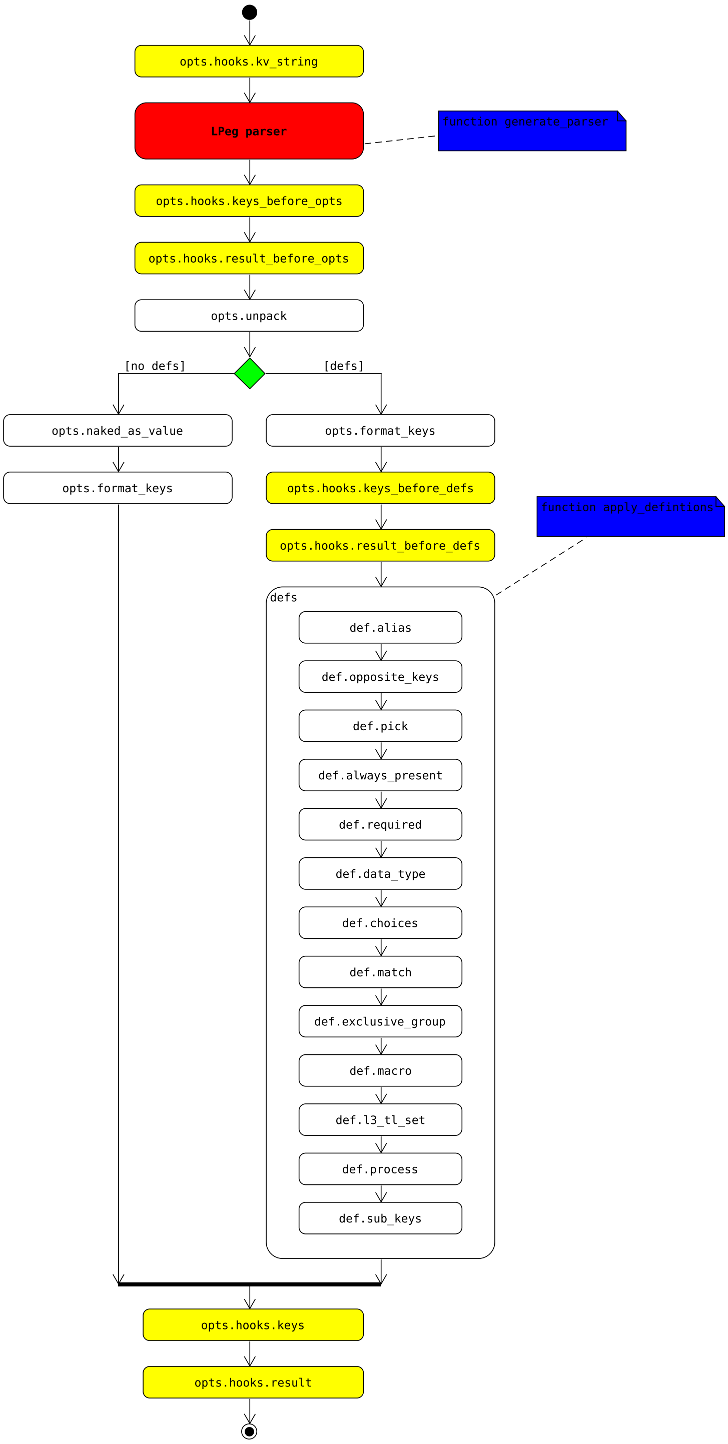
```
\input luakeys-debug.tex
\luakeysdebug{one,two,three}
\bye
```

6.2 For LaTeX: luakeys-debug.sty

An example of how to use the command in LaTeX:

```
\documentclass{article}
\usepackage{luakeys-debug}
\begin{document}
\luakeysdebug[
  unpack=false,
  convert dimensions=false
]{one,two,three}
\end{document}
```

7 Activity diagramm of the parsing process



8 Implementation

8.1 luakeys.lua

```lua
---luakeys.lua
---Copyright 2021-2024 Josef Friedrich
---
---This work may be distributed and/or modified under the
---conditions of the LaTeX Project Public License, either version 1.3c
---of this license or (at your option) any later version.
---The latest version of this license is in
---http://www.latex-project.org/lppl.txt
---and version 1.3c or later is part of all distributions of LaTeX
---version 2008/05/04 or later.
---
---This work has the LPPL maintenance status `maintained'.
---
---The Current Maintainer of this work is Josef Friedrich.
---
---This work consists of the files luakeys.lua, luakeys.sty, luakeys.tex
---luakeys-debug.sty and luakeys-debug.tex.
----A key-value parser written with Lpeg.
---
local lpeg = require('lpeg')

if not tex then
  ---Dummy functions for the tests.
  tex = {
    sp = function(input)
      return 1234567
    end,
  }

  token = {
    set_macro = function(csname, content, global)
    end,
  }
end

---
local utils = (function()
  ---
  ---Merge two tables into the first specified table.
  ---The `merge_tables` function copies keys from the `source` table
  ---to the `target` table. It returns the target table.
  ---
  ---https://stackoverflow.com/a/1283608/10193818
  ---
  ---@param target table # The target table where all values are copied.
  ---@param source table # The source table from which all values are copied.
  ---@param overwrite? boolean # Overwrite the values in the target table if they
  ↪  are present (default true).
  ---
  ---@return table target The modified target table.
  local function merge_tables(target, source, overwrite)
    if overwrite == nil then
      overwrite = true
    end
    for key, value in pairs(source) do
      if type(value) == 'table' and type(target[key] or false) ==
        'table' then
        merge_tables(target[key] or {}, source[key] or {}, overwrite)
      elseif (not overwrite and target[key] == nil) or
        (overwrite and target[key] ~= value) then
        target[key] = value
      end
    end
    return target
  end

  ---
  ---Clone a table, i.e. make a deep copy of the source table.
  ---
  ---http://lua-users.org/wiki/CopyTable
  ---
  ---@param source table # The source table to be cloned.
  ---
  ---@return table # A deep copy of the source table.
  local function clone_table(source)
    local copy
    if type(source) == 'table' then
      copy = {}
      for orig_key, orig_value in next, source, nil do
        copy[clone_table(orig_key)] = clone_table(orig_value)
      end
      setmetatable(copy, clone_table(getmetatable(source)))
    else ---number, string, boolean, etc
      copy = source
    end
    return copy
  end

  ---
  ---Remove an element from a table.
  ---
  ---@param source table # The source table.
  ---@param value any # The value to be removed from the table.
  ---
  ---@return any|nil # If the value was found, then this value, otherwise nil.
  local function remove_from_table(source, value)
    for index, v in pairs(source) do
      if value == v then
        source[index] = nil
        return value
      end
    end
  end

  ---
  ---Return the keys of a table as a sorted list (array like table).
  ---
  ---@param source table # The source table.
  ---
  ---@return table # An array table with the sorted key names.
  local function get_table_keys(source)
    local keys = {}
    for key in pairs(source) do
      table.insert(keys, key)
    end
    table.sort(keys)
    return keys
  end

  ---
```

```lua
---Get the size of a table `{ one = 'one', 'two', 'three' }` = 3.
---
---@param value any # A table or any input.
---
---@return number # The size of the array like table. 0 if the input is no table or the table is empty.
local function get_table_size(value)
  local count = 0
  if type(value) == 'table' then
    for _ in pairs(value) do
      count = count + 1
    end
  end
  return count
end

---
---Get the size of an array like table, for example `{ 'one', 'two',
---'three' }` = 3.
---
---@param value any # A table or any input.
---
---@return number # The size of the array like table. 0 if the input is no table or the table is empty.
local function get_array_size(value)
  local count = 0
  if type(value) == 'table' then
    for _ in ipairs(value) do
      count = count + 1
    end
  end
  return count
end

---
---Print a formatted string.
---
---* `%d` or `%i`: Signed decimal integer
---* `%u`: Unsigned decimal integer
---* `%o`: Unsigned octal
---* `%x`: Unsigned hexadecimal integer
---* `%X`: Unsigned hexadecimal integer (uppercase)
---* `%f`: Decimal floating point, lowercase
---* `%e`: Scientific notation (mantissa/exponent), lowercase
---* `%E`: Scientific notation (mantissa/exponent), uppercase
---* `%g`: Use the shortest representation: %e or %f
---* `%G`: Use the shortest representation: %E or %F
---* `%a`: Hexadecimal floating point, lowercase
---* `%A`: Hexadecimal floating point, uppercase
---* `%c`: Character
---* `%s`: String of characters
---* `%p`: Pointer address        b8000000
---* `%%`: A `%` followed by another `%` character will write a single `%` to the stream.
---* `%q`: formats `booleans`, `nil`, `numbers`, and `strings` in a way that the result is a valid constant in Lua source code.
---
---http://www.lua.org/source/5.3/lstrlib.c.html#str_format
---
---@param format string # A string in the `printf` format
---@param ... any # A sequence of additional arguments, each containing a value to be used to replace a format specifier in the format string.
```

```
local function tex_printf(format, ...)
  tex.print(string.format(format, ...))
end

---
---Throw a single error message.
---
---@param message string
---@param help? table
local function throw_error_message(message, help)
  if type(tex.error) == 'function' then
    tex.error(message, help)
  else
    error(message)
  end
end

---
---Throw an error by specifying an error code.
---
---@param error_messages table
---@param error_code string
---@param args? table
local function throw_error_code(error_messages,
  error_code,
  args)
  local template = error_messages[error_code]

  ---
  ---@param message string
  ---@param a table
  ---
  ---@return string
  local function replace_args(message, a)
    for key, value in pairs(a) do
      if type(value) == 'table' then
        value = table.concat(value, ', ')
      end
      message = message:gsub('@' .. key,
        '"' .. tostring(value) .. '"')
    end
    return message
  end

  ---
  ---@param list table
  ---@param a table
  ---
  ---@return table
  local function replace_args_in_list(list, a)
    for index, message in ipairs(list) do
      list[index] = replace_args(message, a)
    end
    return list
  end

  ---
  ---@type string
  local message
  ---@type table
  local help = {}

```

```
    if type(template) == 'table' then
      message = template[1]
      if args ~= nil then
        help = replace_args_in_list(template[2], args)
      else
        help = template[2]
      end
    else
      message = template
    end

    if args ~= nil then
      message = replace_args(message, args)
    end

    message = 'luakeys error [' .. error_code .. ']: ' .. message

    for _, help_message in ipairs({
      'You may be able to find more help in the documentation:',
      'http://mirrors.ctan.org/macros/luatex/generic/luakeys/luakeys-doc.pdf',
      'Or ask a question in the issue tracker on Github:',
      'https://github.com/Josef-Friedrich/luakeys/issues',
    }) do
      table.insert(help, help_message)
    end

    throw_error_message(message, help)
  end

  local function visit_tree(tree, callback_func)
    if type(tree) ~= 'table' then
      throw_error_message(
        'Parameter "tree" has to be a table, got: ' ..
          tostring(tree))
    end
    local function visit_tree_recursive(tree,
      current,
      result,
      depth,
      callback_func)
      for key, value in pairs(current) do
        if type(value) == 'table' then
          value = visit_tree_recursive(tree, value, {}, depth + 1,
            callback_func)
        end

        key, value = callback_func(key, value, depth, current, tree)

        if key ~= nil and value ~= nil then
          result[key] = value
        end
      end
      if next(result) ~= nil then
        return result
      end
    end

    local result =
      visit_tree_recursive(tree, tree, {}, 1, callback_func)

    if result == nil then
      return {}
```

```lua
  end
  return result
end

---@alias ColorName 'black'|'red'|'green'|'yellow'|'blue'|'magenta'|'cyan'|'white'|'reset'
---@alias ColorMode 'bright'|'dim'

---
---Small library to surround strings with ANSI color codes.
--
---[SGR (Select Graphic Rendition) Parameters](https://en.wikipedia.org/wiki/ANSI_escape_code#SGR_(Select_Graphic_Rendition)_parameters)
---
---__attributes__
---
---| color      |code|
---|------------|----|
---| reset      |  0 |
---| clear      |  0 |
---| bright     |  1 |
---| dim        |  2 |
---| underscore |  4 |
---| blink      |  5 |
---| reverse    |  7 |
---| hidden     |  8 |
---
---__foreground__
---
---| color      |code|
---|------------|----|
---| black      | 30 |
---| red        | 31 |
---| green      | 32 |
---| yellow     | 33 |
---| blue       | 34 |
---| magenta    | 35 |
---| cyan       | 36 |
---| white      | 37 |
---
---__background__
---
---| color      |code|
---|------------|----|
---| onblack    | 40 |
---| onred      | 41 |
---| ongreen    | 42 |
---| onyellow   | 43 |
---| onblue     | 44 |
---| onmagenta  | 45 |
---| oncyan     | 46 |
---| onwhite    | 47 |
local ansi_color = (function()

  ---
  ---@param code integer
  ---
  ---@return string
  local function format_color_code(code)
    return string.char(27) .. '[' .. tostring(code) .. 'm'
  end

```

```
---
---@private
---
---@param color ColorName # A color name.
---@param mode? ColorMode
---@param background? boolean # Colorize the background not the text.
---
---@return string
local function get_color_code(color, mode, background)
  local output = ''
  local code

  if mode == 'bright' then
    output = format_color_code(1)
  elseif mode == 'dim' then
    output = format_color_code(2)
  end

  if not background then
    if color == 'reset' then
      code = 0
    elseif color == 'black' then
      code = 30
    elseif color == 'red' then
      code = 31
    elseif color == 'green' then
      code = 32
    elseif color == 'yellow' then
      code = 33
    elseif color == 'blue' then
      code = 34
    elseif color == 'magenta' then
      code = 35
    elseif color == 'cyan' then
      code = 36
    elseif color == 'white' then
      code = 37
    else
      code = 37
    end
  else
    if color == 'black' then
      code = 40
    elseif color == 'red' then
      code = 41
    elseif color == 'green' then
      code = 42
    elseif color == 'yellow' then
      code = 43
    elseif color == 'blue' then
      code = 44
    elseif color == 'magenta' then
      code = 45
    elseif color == 'cyan' then
      code = 46
    elseif color == 'white' then
      code = 47
    else
      code = 40
    end
  end
  return output .. format_color_code(code)
```

```
end

---
---@param text any
---@param color ColorName # A color name.
---@param mode? ColorMode
---@param background? boolean # Colorize the background not the text.
---
---@return string
local function colorize(text, color, mode, background)
  return string.format('%s%s%s',
    get_color_code(color, mode, background), text,
    get_color_code('reset'))
end

return {
  colorize = colorize,

  ---
  ---@param text any
  ---
  ---@return string
  red = function(text)
    return colorize(text, 'red')
  end,

  ---
  ---@param text any
  ---
  ---@return string
  green = function(text)
    return colorize(text, 'green')
  end,

  ---@return string
  yellow = function(text)
    return colorize(text, 'yellow')
  end,

  ---
  ---@param text any
  ---
  ---@return string
  blue = function(text)
    return colorize(text, 'blue')
  end,

  ---
  ---@param text any
  ---
  ---@return string
  magenta = function(text)
    return colorize(text, 'magenta')
  end,

  ---
  ---@param text any
  ---
  ---@return string
  cyan = function(text)
    return colorize(text, 'cyan')
  end,
  }
end)()

---
---A small logging library.
---
---Log levels:
---
---* 0: silent
---* 1: error (red)
---* 2: warn (yellow)
---* 3: info (green)
---* 4: verbose (blue)
---* 5: debug (magenta)
---
local log = (function()
  ---@private
  local opts = { level = 0 }

  local function colorize_not(s)
    return s
  end

  local colorize = colorize_not

  ---@private
  local function print_message(message, ...)
    local args = { ... }
    for index, value in ipairs(args) do
      args[index] = colorize(value)
    end
    print(string.format(message, table.unpack(args)))
  end

  ---
  ---Set the log level.
  ---
  ---@param level 0|'silent'|1|'error'|2|'warn'|3|'info'|4|'verbose'|5|'debug'
  local function set_log_level(level)
    if type(level) == 'string' then
      if level == 'silent' then
        opts.level = 0
      elseif level == 'error' then
        opts.level = 1
      elseif level == 'warn' then
        opts.level = 2
      elseif level == 'info' then
        opts.level = 3
      elseif level == 'verbose' then
        opts.level = 4
      elseif level == 'debug' then
        opts.level = 5
      else
        throw_error_message(string.format('Unknown log level: %s',
          level))
      end
    else
      if level > 5 or level < 0 then
        throw_error_message(string.format(
          'Log level out of range 0-5: %s', level))
      end
      opts.level = level
```

```lua
  end
end

---
---@return integer
local function get_log_level()
  return opts.level
end

---
---Log at level 1 (error).
---
---The other log levels are: 0 (silent), 1 (error), 2 (warn), 3 (info), 4
↪  (verbose), 5 (debug).
---
---@param message string
---@param ... any
local function error(message, ...)
  if opts.level >= 1 then
    colorize = ansi_color.red
    print_message(message, ...)
    colorize = colorize_not
  end
end

---
---Log at level 2 (warn).
---
---The other log levels are: 0 (silent), 1 (error), 2 (warn), 3 (info), 4
↪  (verbose), 5 (debug).
---
---@param message string
---@param ... any
local function warn(message, ...)
  if opts.level >= 2 then
    colorize = ansi_color.yellow
    print_message(message, ...)
    colorize = colorize_not
  end
end

---
---Log at level 3 (info).
---
---The other log levels are: 0 (silent), 1 (error), 2 (warn), 3 (info), 4
↪  (verbose), 5 (debug).
---
---@param message string
---@param ... any
local function info(message, ...)
  if opts.level >= 3 then
    colorize = ansi_color.green
    print_message(message, ...)
    colorize = colorize_not
  end
end

---
---Log at level 4 (verbose).
---
---The other log levels are: 0 (silent), 1 (error), 2 (warn), 3 (info), 4
↪  (verbose), 5 (debug).
```

```
    ---
    ---@param message string
    ---@param ... any
    local function verbose(message, ...)
      if opts.level >= 4 then
        colorize = ansi_color.blue
        print_message(message, ...)
        colorize = colorize_not
      end
    end

    ---
    ---Log at level 5 (debug).
    ---
    ---The other log levels are: 0 (silent), 1 (error), 2 (warn), 3 (info), 4 (verbose), 5 (debug).
    ---
    ---@param message string
    ---@param ... any
    local function debug(message, ...)
      if opts.level >= 5 then
        colorize = ansi_color.magenta
        print_message(message, ...)
        colorize = colorize_not
      end
    end

    return {
      set = set_log_level,
      get = get_log_level,
      error = error,
      warn = warn,
      info = info,
      verbose = verbose,
      debug = debug,
    }
  end)()

  return {
    merge_tables = merge_tables,
    clone_table = clone_table,
    remove_from_table = remove_from_table,
    get_table_keys = get_table_keys,
    get_table_size = get_table_size,
    get_array_size = get_array_size,
    visit_tree = visit_tree,
    tex_printf = tex_printf,
    throw_error_message = throw_error_message,
    throw_error_code = throw_error_code,
    ansi_color = ansi_color,
    log = log,
  }
end)()

---
---Convert back to strings
---@section
local visualizers = (function()

  ---
  ---Reverse the function
  ---`parse(kv_string)`. It takes a Lua table and converts this table
```

```
---into a key-value string. The resulting string usually has a
---different order as the input table. In Lua only tables with
---1-based consecutive integer keys (a.k.a. array tables) can be
---parsed in order.
---
---@param result table # A table to be converted into a key-value string.
---
---@return string # A key-value string that can be passed to a TeX macro.
local function render(result)
  local function render_inner(result)
    local output = {}
    local function add(text)
      table.insert(output, text)
    end
    for key, value in pairs(result) do
      if (key and type(key) == 'string') then
        if (type(value) == 'table') then
          if (next(value)) then
            add(key .. '={')
            add(render_inner(value))
            add('},')
          else
            add(key .. '={},')
          end
        else
          add(key .. '=' .. tostring(value) .. ',')
        end
      else
        add(tostring(value) .. ',')
      end
    end
    return table.concat(output)
  end
  return render_inner(result)
end

---
---The function `stringify(tbl, for_tex)` converts a Lua table into a
---printable string. Stringify a table means to convert the table into
---a string. This function is used to realize the `debug` function.
---`stringify(tbl, true)` (`for_tex = true`) generates a string which
---can be embeded into TeX documents. The macro `\luakeysdebug{}` uses
---this option. `stringify(tbl, false)` or `stringify(tbl)` generate a
---string suitable for the terminal.
---
---@see https://stackoverflow.com/a/54593224/10193818
---
---@param result table # A table to stringify.
---@param for_tex? boolean # Stringify the table into a text string that can be
↪  embeded inside a TeX document via tex.print(). Curly braces and whites spaces
↪  are escaped.
---
---@return string
local function stringify(result, for_tex)
  local line_break, start_bracket, end_bracket, indent

  if for_tex then
    line_break = '\\par'
    start_bracket = '$\\{$'
    end_bracket = '$\\}$'
    indent = '\\ \\ '
  else
```

```
    line_break = '\n'
    start_bracket = '{'
    end_bracket = '}'
    indent = '  '
  end

  local function stringify_inner(input, depth)
    local output = {}
    depth = depth or 0

    local function add(depth, text)
      table.insert(output, string.rep(indent, depth) .. text)
    end

    local function format_key(key)
      if (type(key) == 'number') then
        return string.format('[%s]', key)
      else
        return string.format('[\'%s\']', key)
      end
    end

    if type(input) ~= 'table' then
      return tostring(input)
    end

    for key, value in pairs(input) do
      if (key and type(key) == 'number' or type(key) == 'string') then
        key = format_key(key)

        if (type(value) == 'table') then
          if (next(value)) then
            add(depth, key .. ' = ' .. start_bracket)
            add(0, stringify_inner(value, depth + 1))
            add(depth, end_bracket .. ',');
          else
            add(depth,
              key .. ' = ' .. start_bracket .. end_bracket .. ',')
          end
        else
          if (type(value) == 'string') then
            value = string.format('\'%s\'', value)
          else
            value = tostring(value)
          end

          add(depth, key .. ' = ' .. value .. ',')
        end
      end
    end

    return table.concat(output, line_break)
  end

  return start_bracket .. line_break .. stringify_inner(result, 1) ..
           line_break .. end_bracket
end

---
---The function `debug(result)` pretty prints a Lua table to standard
---output (stdout). It is a utility function that can be used to
---debug and inspect the resulting Lua table of the function
```

```lua
  ---`parse`. You have to compile your TeX document in a console to
  ---see the terminal output.
  ---
  ---@param result table # A table to be printed to standard output for debugging purposes.
  local function debug(result)
    print('\n' .. stringify(result, false))
  end

  return { render = render, stringify = stringify, debug = debug }
end)()

---@class OptionCollection
---@field accumulated_result? table
---@field assignment_operator? string # default `=`
---@field convert_dimensions? boolean # default `false`
---@field debug? boolean # default `false`
---@field default? boolean # default `true`
---@field defaults? table
---@field defs? DefinitionCollection
---@field false_aliases? table default `{ 'false', 'FALSE', 'False' }`,
---@field format_keys? boolean # default `false`,
---@field group_begin? string default `{`,
---@field group_end? string default `}`,
---@field hooks? HookCollection
---@field invert_flag? string default `!`
---@field list_separator? string default `,`
---@field naked_as_value? boolean # default `false`
---@field no_error? boolean # default `false`
---@field quotation_begin? string `"`
---@field quotation_end? string `"`
---@field true_aliases? table `{ 'true', 'TRUE', 'True' }`
---@field unpack? boolean # default `true`

---@alias KeysHook fun(key: string, value: any, depth: integer, current: table, result: table): string, any
---@alias ResultHook fun(result: table): nil

---@class HookCollection
---@field kv_string? fun(kv_string: string): string
---@field keys_before_opts? KeysHook
---@field result_before_opts? ResultHook
---@field keys_before_def? KeysHook
---@field result_before_def? ResultHook
---@field keys? KeysHook
---@field result? ResultHook

---@alias ProcessFunction fun(value: any, input: table, result: table, unknown: table): any

---@alias PickDataType 'string'|'number'|'dimension'|'integer'|'boolean'|'any'

---@class Definition
---@field alias? string|table
---@field always_present? boolean
---@field choices? table
---@field data_type? 'boolean'|'dimension'|'integer'|'number'|'string'|'list'
---@field default? any
---@field description? string
---@field exclusive_group? string
---@field l3_tl_set? string
---@field macro? string
```

```lua
---@field match? string
---@field name? string
---@field opposite_keys? table
---@field pick? PickDataType|PickDataType[]|false
---@field process? ProcessFunction
---@field required? boolean
---@field sub_keys? table<string, Definition>

---@alias DefinitionCollection table<string|number, Definition>

local namespace = {
  opts = {
    accumulated_result = false,
    assignment_operator = '=',
    convert_dimensions = false,
    debug = false,
    default = true,
    defaults = false,
    defs = false,
    false_aliases = { 'false', 'FALSE', 'False' },
    format_keys = false,
    group_begin = '{',
    group_end = '}',
    hooks = {},
    invert_flag = '!',
    list_separator = ',',
    naked_as_value = false,
    no_error = false,
    quotation_begin = '"',
    quotation_end = '"',
    true_aliases = { 'true', 'TRUE', 'True' },
    unpack = true,
  },

  hooks = {
    kv_string = true,
    keys_before_opts = true,
    result_before_opts = true,
    keys_before_def = true,
    result_before_def = true,
    keys = true,
    result = true,
  },

  attrs = {
    alias = true,
    always_present = true,
    choices = true,
    data_type = true,
    default = true,
    description = true,
    exclusive_group = true,
    l3_tl_set = true,
    macro = true,
    match = true,
    name = true,
    opposite_keys = true,
    pick = true,
    process = true,
    required = true,
    sub_keys = true,
  },

  error_messages = {
    E001 = {
      'Unknown parse option: @unknown!',
      { 'The available options are:', '@opt_names' },
    },
    E002 = {
      'Unknown hook: @unknown!',
      { 'The available hooks are:', '@hook_names' },
    },
    E003 = 'Duplicate aliases @alias1 and @alias2 for key @key!',
    E004 = 'The value @value does not exist in the choices: @choices',
    E005 = 'Unknown data type: @unknown',
    E006 = 'The value @value of the key @key could not be converted into the data type @data_type!',
    E007 = 'The key @key belongs to the mutually exclusive group @exclusive_group and another key of the group named @another_key is already present!',
    E008 = 'def.match has to be a string',
    E009 = 'The value @value of the key @key does not match @match!',

    E011 = 'Wrong data type in the "pick" attribute: @unknown. Allowed are: @data_types.',
    E012 = 'Missing required key @key!',
    E013 = 'The key definition must be a table! Got @data_type for key @key.',
    E014 = {
      'Unknown definition attribute: @unknown',
      { 'The available attributes are:', '@attr_names' },
    },
    E015 = 'Key name couldn’t be detected!',
    E017 = 'Unknown style to format keys: @unknown! Allowed styles are: @styles',
    E018 = 'The option "format_keys" has to be a table not @data_type',
    E019 = 'Unknown keys: @unknown',

    ---Input / parsing error
    E021 = 'Opposite key was specified more than once: @key!',
    E020 = 'Both opposite keys were given: @true and @false!',
    ---Config error (wrong configuration of luakeys)
    E010 = 'Usage: opposite_keys = { "true_key", "false_key" } or { [true] = "true_key", [false] = "false_key" } ',
    E023 = {
      'Don’t use this function from the global luakeys table. Create a new instance using e. g.: local lk = luakeys.new()',
      {
        'This functions should not be used from the global luakeys table:',
        'parse()',
        'save()',
        'get()',
      },
    },
  },
}

---
---Main entry point of the module.
---
---The return value is intentional not documented so the Lua language server can figure out the types.
local function main()

  ---The default options.
  ---@type OptionCollection
  local default_opts = utils.clone_table(namespace.opts)
```

```lua

local error_messages = utils.clone_table(namespace.error_messages)

---
---@param error_code string
---@param args? table
local function throw_error(error_code, args)
  utils.throw_error_code(error_messages, error_code, args)
end

---
---Normalize the parse options.
---
---@param opts? OptionCollection|unknown # Options in a raw format. The table may be empty or some keys are not set.
---
---@return OptionCollection
local function normalize_opts(opts)
  if type(opts) ~= 'table' then
    opts = {}
  end
  for key, _ in pairs(opts) do
    if namespace.opts[key] == nil then
      throw_error('E001', {
        unknown = key,
        opt_names = utils.get_table_keys(namespace.opts),
      })
    end
  end
  local old_opts = opts
  opts = {}
  for name, _ in pairs(namespace.opts) do
    if old_opts[name] ~= nil then
      opts[name] = old_opts[name]
    else
      opts[name] = default_opts[name]
    end
  end

  for hook in pairs(opts.hooks) do
    if namespace.hooks[hook] == nil then
      throw_error('E002', {
        unknown = hook,
        hook_names = utils.get_table_keys(namespace.hooks),
      })
    end
  end
  return opts
end

local l3_code_cctab = 10

---
---Parser / Lpeg related
---@section

---Generate the PEG parser using Lpeg.
---
---Explanations of some LPeg notation forms:
---
---* `patt ^ 0` = `expression *`
---* `patt ^ 1` = `expression +`
```

```lua
---* `patt ^ -1` = `expression ?`
---* `patt1 * patt2` = `expression1 expression2`: Sequence
---* `patt1 + patt2` = `expression1 / expression2`: Ordered choice
---
---* [TUGboat article: Parsing complex data formats in LuaTEX with LPEG](https://tug.or-g/TUGboat/tb40-2/tb125menke-Patterndf)
---
---@param initial_rule string # The name of the first rule of the grammar table passed to the `lpeg.P(attern)` function (e. g. `list`, `number`).
---@param opts? table # Whether the dimensions should be converted to scaled points (by default `false`).
---
---@return userdata # The parser.
local function generate_parser(initial_rule, opts)
  if type(opts) ~= 'table' then
    opts = normalize_opts(opts)
  end

  local Variable = lpeg.V
  local Pattern = lpeg.P
  local Set = lpeg.S
  local Range = lpeg.R
  local CaptureGroup = lpeg.Cg
  local CaptureFolding = lpeg.Cf
  local CaptureTable = lpeg.Ct
  local CaptureConstant = lpeg.Cc
  local CaptureSimple = lpeg.C

  ---Optional whitespace
  local white_space = Set(' \t\n\r')

  ---Match literal string surrounded by whitespace
  local ws = function(match)
    return white_space ^ 0 * Pattern(match) * white_space ^ 0
  end

  local line_up_pattern = function(patterns)
    local result
    for _, pattern in ipairs(patterns) do
      if result == nil then
        result = Pattern(pattern)
      else
        result = result + Pattern(pattern)
      end
    end
    return result
  end

  ---
  ---Convert a dimension to an normalized dimension string or an
  ---integer in the scaled points format.
  ---
  ---@param input string
  ---
  ---@return integer|string # A dimension as an integer or a dimension string.
  local capture_dimension = function(input)
    ---Remove all whitespaces
    input = input:gsub('%s+', '')
    ---Convert the unit string into lowercase.
    input = input:lower()
    if opts.convert_dimensions then
      return tex.sp(input)
    else
      return input
    end
  end

  ---
  ---Add values to a table in two modes:
  ---
  ---Key-value pair:
  ---
  ---If `arg1` and `arg2` are not nil, then `arg1` is the key and `arg2` is the
  ---value of a new table entry.
  ---
  ---Indexed value:
  ---
  ---If `arg2` is nil, then `arg1` is the value and is added as an indexed
  ---(by an integer) value.
  ---
  ---@param result table # The result table to which an additional key-value pair
  ↪  or value should to be added
  ---@param arg1 any # The key or the value.
  ---@param arg2? any # Always the value.
  ---
  ---@return table # The result table to which an additional key-value pair or
  ↪  value has been added.
  local add_to_table = function(result, arg1, arg2)
    if arg2 == nil then
      local index = #result + 1
      return rawset(result, index, arg1)
    else
      return rawset(result, arg1, arg2)
    end
  end

  -- LuaFormatter off
  return Pattern({
    [1] = initial_rule,

    ---list_item*
    list = CaptureFolding(
      CaptureTable('') * Variable('list_item')^0,
      add_to_table
    ),

    ---'{' list '}'
    list_container =
      ws(opts.group_begin) * Variable('list') * ws(opts.group_end),

    ---( list_container / key_value_pair / value ) ','?
    list_item =
      CaptureGroup(
        Variable('list_container') +
        Variable('key_value_pair') +
        Variable('value')
      ) * ws(opts.list_separator)^-1,

    ---key '=' (list_container / value)
    key_value_pair =
      (Variable('key') * ws(opts.assignment_operator)) *
      ↪  (Variable('list_container') + Variable('value')),

    ---number / string_quoted / string_unquoted
```

```
      key =
        Variable('number') +
        Variable('string_quoted') +
        Variable('string_unquoted'),

      ---boolean !value / dimension !value / number !value / string_quoted !value /
      ↪  string_unquoted
      ---!value -> Not-predicate -> * -Variable('value')
      value =
        Variable('boolean') * -Variable('value') +
        Variable('dimension') * -Variable('value') +
        Variable('number') * -Variable('value')  +
        Variable('string_quoted') * -Variable('value') +
        Variable('string_unquoted'),

      ---for is.boolean()
      boolean_only = Variable('boolean') * -1,

      ---boolean_true / boolean_false
      boolean =
        (
          Variable('boolean_true') * CaptureConstant(true) +
          Variable('boolean_false') * CaptureConstant(false)
        ),

      boolean_true = line_up_pattern(opts.true_aliases),

      boolean_false = line_up_pattern(opts.false_aliases),

      ---for is.dimension()
      dimension_only = Variable('dimension') * -1,

      dimension = (
        Variable('tex_number') * white_space^0 *
        Variable('unit')
      ) / capture_dimension,

      sign = Set('-+'),

      digit = Range('09'),

      integer = (Variable('sign')^-1) * white_space^0 * (Variable('digit')^1),

      fractional = (Pattern('.') ) * (Variable('digit')^1),

      ---(integer fractional?) / (sign? white_space? fractional)
      tex_number = (Variable('integer') * (Variable('fractional')^-1)) +
                   ((Variable('sign')^-1) * white_space^0 *
                   ↪  Variable('fractional')),

      ---for is.number()
      number_only = Variable('number') * -1,

      ---capture number
      number = Variable('tex_number') / tonumber,

      ---'bp' / 'BP' / 'cc' / etc.

      ↪  ---https://raw.githubusercontent.com/latex3/lualibs/master/lualibs-util-dim.lua

      ↪  ---https://github.com/TeX-Live/luatex/blob/51db1985f5500dafd2393aa2e403fefa57d3cb76/source/texk/we
      unit =
        Pattern('bp') + Pattern('BP') +
        Pattern('cc') + Pattern('CC') +
        Pattern('cm') + Pattern('CM') +
        Pattern('dd') + Pattern('DD') +
        Pattern('em') + Pattern('EM') +
        Pattern('ex') + Pattern('EX') +
        Pattern('in') + Pattern('IN') +
        Pattern('mm') + Pattern('MM') +
        Pattern('mu') + Pattern('MU') +
        Pattern('nc') + Pattern('NC') +
        Pattern('nd') + Pattern('ND') +
        Pattern('pc') + Pattern('PC') +
        Pattern('pt') + Pattern('PT') +
        Pattern('px') + Pattern('PX') +
        Pattern('sp') + Pattern('SP'),

      ---'"' ('\"' / !'"')* '"'
      string_quoted =
        white_space^0 * Pattern(opts.quotation_begin) *
        CaptureSimple((Pattern('\\' .. opts.quotation_end) + 1 - Pattern(opts.quotation_end))^0) *
        Pattern(opts.quotation_end) * white_space^0,

      string_unquoted =
        white_space^0 *
        CaptureSimple(
          Variable('word_unquoted')^1 *
          (Set(' \t')^1 * Variable('word_unquoted')^1)^0) *
        white_space^0,

      word_unquoted = (1 - white_space - Set(
        opts.group_begin ..
        opts.group_end ..
        opts.assignment_operator  ..
        opts.list_separator))^1
    })
-- LuaFormatter on
  end

  local is = {
    boolean = function(value)
      if value == nil then
        return false
      end
      if type(value) == 'boolean' then
        return true
      end
      local parser = generate_parser('boolean_only')
      local result = parser:match(tostring(value))
      return result ~= nil
    end,

    dimension = function(value)
      if value == nil then
        return false
      end
      local parser = generate_parser('dimension_only')
      local result = parser:match(tostring(value))
      return result ~= nil
    end,

    integer = function(value)
      local n = tonumber(value)
      if n == nil then
        return false
      end
      return n == math.floor(n)
    end,

    number = function(value)
      if value == nil then
        return false
      end
      if type(value) == 'number' then
        return true
      end
      local parser = generate_parser('number_only')
      local result = parser:match(tostring(value))
      return result ~= nil
    end,

    string = function(value)
      return type(value) == 'string'
    end,

    list = function(value)
      if type(value) ~= 'table' then
        return false
      end

      for k, _ in pairs(value) do
        if type(k) ~= 'number' then
          return false
        end
      end
      return true
    end,

    any = function(value)
      return true
    end,
  }

  ---
  ---Apply the key-value-pair definitions (defs) on an input table in a
  ---recursive fashion.
  ---
  ---@param defs table # A table containing all definitions.
  ---@param opts table # The parse options table.
  ---@param input table # The current input table.
  ---@param output table # The current output table.
  ---@param unknown table # Always the root unknown table.
  ---@param key_path table # An array of key names leading to the current
  ---@param input_root table # The root input table input and output table.
  local function apply_definitions(defs,
    opts,
    input,
    output,
    unknown,
    key_path,
    input_root)
    local exclusive_groups = {}

    local function add_to_key_path(key_path, key)
```

```
      local new_key_path = {}

      for index, value in ipairs(key_path) do
        new_key_path[index] = value
      end

      table.insert(new_key_path, key)
      return new_key_path
    end

    local function get_default_value(def)
      if def.default ~= nil then
        return def.default
      elseif opts ~= nil and opts.default ~= nil then
        return opts.default
      end
      return true
    end

    local function find_value(search_key, def)
      if input[search_key] ~= nil then
        local value = input[search_key]
        input[search_key] = nil
        return value
        ---naked keys: values with integer keys
      elseif utils.remove_from_table(input, search_key) ~= nil then
        return get_default_value(def)
      end
    end

    local apply = {
      alias = function(value, key, def)
        if type(def.alias) == 'string' then
          def.alias = { def.alias }
        end
        local alias_value
        local used_alias_key
        ---To get an error if the key and an alias is present
        if value ~= nil then
          alias_value = value
          used_alias_key = key
        end
        for _, alias in ipairs(def.alias) do
          local v = find_value(alias, def)
          if v ~= nil then
            if alias_value ~= nil then
              throw_error('E003', {
                alias1 = used_alias_key,
                alias2 = alias,
                key = key,
              })
            end
            used_alias_key = alias
            alias_value = v
          end
        end
        if alias_value ~= nil then
          return alias_value
        end
      end,

      always_present = function(value, key, def)
        if value == nil and def.always_present then
          return get_default_value(def)
        end
      end,

      choices = function(value, key, def)
        if value == nil then
          return
        end
        if def.choices ~= nil and type(def.choices) == 'table' then
          local is_in_choices = false
          for _, choice in ipairs(def.choices) do
            if value == choice then
              is_in_choices = true
            end
          end
          if not is_in_choices then
            throw_error('E004', { value = value, choices = def.choices })
          end
        end
      end,

      data_type = function(value, key, def)
        if value == nil then
          return
        end
        if def.data_type ~= nil then
          local converted
          ---boolean
          if def.data_type == 'boolean' then
            if value == 0 or value == '' or not value then
              converted = false
            else
              converted = true
            end
            ---dimension
          elseif def.data_type == 'dimension' then
            if is.dimension(value) then
              converted = value
            end
            ---integer
          elseif def.data_type == 'integer' then
            if is.number(value) then
              local n = tonumber(value)
              if type(n) == 'number' and n ~= nil then
                converted = math.floor(n)
              end
            end
            ---number
          elseif def.data_type == 'number' then
            if is.number(value) then
              converted = tonumber(value)
            end
            ---string
          elseif def.data_type == 'string' then
            converted = tostring(value)
            ---list
          elseif def.data_type == 'list' then
            if is.list(value) then
              converted = value
            end
          else
```

```
          throw_error('E005', { data_type = def.data_type })
        end
        if converted == nil then
          throw_error('E006', {
            value = value,
            key = key,
            data_type = def.data_type,
          })
        else
          return converted
        end
      end
    end,

    exclusive_group = function(value, key, def)
      if value == nil then
        return
      end
      if def.exclusive_group ~= nil then
        if exclusive_groups[def.exclusive_group] ~= nil then
          throw_error('E007', {
            key = key,
            exclusive_group = def.exclusive_group,
            another_key = exclusive_groups[def.exclusive_group],
          })
        else
          exclusive_groups[def.exclusive_group] = key
        end
      end
    end,

    l3_tl_set = function(value, key, def)
      if value == nil then
        return
      end
      if def.l3_tl_set ~= nil then
        tex.print(l3_code_cctab,
          '\\tl_set:Nn \\g_' .. def.l3_tl_set .. '_tl')
        tex.print('{' .. value .. '}')
      end
    end,

    macro = function(value, key, def)
      if value == nil then
        return
      end
      if def.macro ~= nil then
        token.set_macro(def.macro, value, 'global')
      end
    end,

    match = function(value, key, def)
      if value == nil then
        return
      end
      if def.match ~= nil then
        if type(def.match) ~= 'string' then
          throw_error('E008')
        end
        local match = string.match(value, def.match)
        if match == nil then
          throw_error('E009', {
```

```
        value = value,
        key = key,
        match = def.match:gsub('%%', '%%%%'),
      })
    else
      return match
    end
  end
end,

opposite_keys = function(value, key, def)
  if def.opposite_keys ~= nil then
    local function get_value(key1, key2)
      local opposite_name
      if def.opposite_keys[key1] ~= nil then
        opposite_name = def.opposite_keys[key1]
      elseif def.opposite_keys[key2] ~= nil then
        opposite_name = def.opposite_keys[key2]
      end
      return opposite_name
    end
    local true_key = get_value(true, 1)
    local false_key = get_value(false, 2)
    if true_key == nil or false_key == nil then
      throw_error('E010')
    end

    ---@param v string
    local function remove_values(v)
      local count = 0
      while utils.remove_from_table(input, v) do
        count = count + 1
      end
      return count
    end

    local true_count = remove_values(true_key)
    local false_count = remove_values(false_key)

    if true_count > 1 then
      throw_error('E021', { key = true_key })
    end

    if false_count > 1 then
      throw_error('E021', { key = false_key })
    end

    if true_count > 0 and false_count > 0 then
      throw_error('E020',
        { ['true'] = true_key, ['false'] = false_key })
    end
    if true_count == 0 and false_count == 0 then
      return
    end
    return true_count == 1 or false_count == 0
  end
end,

process = function(value, key, def)
  if value == nil then
    return
  end
```

```
      if def.process ~= nil and type(def.process) == 'function' then
        return def.process(value, input_root, output, unknown)
      end
    end,

    pick = function(value, key, def)
      if def.pick then
        local pick_types

        ---Allow old deprecated attribut pick = true
        if def.pick == true then
          pick_types = { 'any' }
        elseif type(def.pick) == 'table' then
          pick_types = def.pick
        else
          pick_types = { def.pick }
        end

        ---Check if the pick attribute is valid
        for _, pick_type in ipairs(pick_types) do
          if type(pick_type) == 'string' and is[pick_type] == nil then
            throw_error('E011', {
              unknown = tostring(pick_type),
              data_types = {
                'any',
                'boolean',
                'dimension',
                'integer',
                'number',
                'string',
              },
            })
          end
        end

        ---The key has already a value. We leave the function at this
        ---point to be able to check the pick attribute for errors
        ---beforehand.
        if value ~= nil then
          return value
        end

        for _, pick_type in ipairs(pick_types) do
          for i, v in pairs(input) do
            ---We can not use ipairs here. `ipairs(t)` iterates up to the
            ---first absent index. Values are deleted from the `input`
            ---table.
            if type(i) == 'number' then
              local picked_value = nil
              if is[pick_type](v) then
                picked_value = v
              elseif pick_type == 'string' and is.number(v) then
                picked_value = tostring(v)
              end

              if picked_value ~= nil then
                input[i] = nil
                return picked_value
              end
            end
          end
        end
      end
    end,

    required = function(value, key, def)
      if def.required ~= nil and def.required and value == nil then
        throw_error('E012', { key = key })
      end
    end,

    sub_keys = function(value, key, def)
      if def.sub_keys ~= nil then
        local v
        ---To get keys defined with always_present
        if value == nil then
          v = {}
        elseif type(value) == 'string' then
          v = { value }
        elseif type(value) == 'table' then
          v = value
        end
        v = apply_definitions(def.sub_keys, opts, v, output[key],
          unknown, add_to_key_path(key_path, key), input_root)
        if utils.get_table_size(v) > 0 then
          return v
        end
      end
    end,
  }

  ---standalone values are removed.
  ---For some callbacks and the third return value of parse, we
  ---need an unchanged raw result from the parse function.
  input = utils.clone_table(input)
  if output == nil then
    output = {}
  end
  if unknown == nil then
    unknown = {}
  end
  if key_path == nil then
    key_path = {}
  end

  for index, def in pairs(defs) do
    ---Find key and def
    local key
    ---`{ key1 = { }, key2 = { } }`
    if type(def) == 'table' and def.name == nil and type(index) ==
      'string' then
      key = index
      ---`{ { name = 'key1' }, { name = 'key2' } }`
    elseif type(def) == 'table' and def.name ~= nil then
      key = def.name
      ---Definitions as strings in an array: `{ 'key1', 'key2' }`
    elseif type(index) == 'number' and type(def) == 'string' then
      key = def
      def = { default = get_default_value({}) }
    end

    if type(def) ~= 'table' then
      throw_error('E013', { data_type = tostring(def), key = index }) ---key is
      ↪  nil
    end

    for attr, _ in pairs(def) do
      if namespace.attrs[attr] == nil then
        throw_error('E014', {
          unknown = attr,
          attr_names = utils.get_table_keys(namespace.attrs),
        })
      end
    end

    if key == nil then
      throw_error('E015')
    end

    local value = find_value(key, def)

    for _, def_opt in ipairs({
      'alias',
      'opposite_keys',
      'pick',
      'always_present',
      'required',
      'data_type',
      'choices',
      'match',
      'exclusive_group',
      'macro',
      'l3_tl_set',
      'process',
      'sub_keys',
    }) do
      if def[def_opt] ~= nil then
        local tmp_value = apply[def_opt](value, key, def)
        if tmp_value ~= nil then
          value = tmp_value
        end
      end
    end

    output[key] = value
  end

  if utils.get_table_size(input) > 0 then
    ---Move to the current unknown table.
    local current_unknown = unknown
    for _, key in ipairs(key_path) do
      if current_unknown[key] == nil then
        current_unknown[key] = {}
      end
      current_unknown = current_unknown[key]
    end

    ---Copy all unknown key-value-pairs to the current unknown table.
    for key, value in pairs(input) do
      current_unknown[key] = value
    end
  end

  return output, unknown
end
```

```lua
---
---Parse a LaTeX/TeX style key-value string into a Lua table.
---
---@param kv_string string # A string in the TeX/LaTeX style key-value format as described above.
---@param opts? OptionCollection # A table containing options.
---
---@return table result # The final result of all individual parsing and normalization steps.
---@return table unknown # A table with unknown, undefinied key-value pairs.
---@return table raw # The unprocessed, raw result of the LPeg parser.
local function parse(kv_string, opts)
  opts = normalize_opts(opts)

  local function log_result(caption, result)
    utils.log
      .debug('%s: \n%s', caption, visualizers.stringify(result))
  end

  if kv_string == nil then
    return {}, {}, {}
  end

  if opts.debug then
    utils.log.set('debug')
  end

  utils.log.debug('kv_string: "%s"', kv_string)

  if type(opts.hooks.kv_string) == 'function' then
    kv_string = opts.hooks.kv_string(kv_string)
  end

  local result = generate_parser('list', opts):match(kv_string)
  local raw = utils.clone_table(result)

  log_result('result after Lpeg Parsing', result)

  local function apply_hook(name)
    if type(opts.hooks[name]) == 'function' then
      if name:match('^keys') then
        result = utils.visit_tree(result, opts.hooks[name])
      else
        opts.hooks[name](result)
      end

      if opts.debug then
        print('After the execution of the hook: ' .. name)
        visualizers.debug(result)
      end
    end
  end

  local function apply_hooks(at)
    if at ~= nil then
      at = '_' .. at
    else
      at = ''
    end
    apply_hook('keys' .. at)
    apply_hook('result' .. at)
  end
```

```

apply_hooks('before_opts')

log_result('after hooks before_opts', result)

---
---Normalize the result table of the LPeg parser. This normalization
---tasks are performed on the raw input table coming directly from
---the PEG parser:
--
---@param result table # The raw input table coming directly from the PEG parser
---@param opts table # Some options.
local function apply_opts(result, opts)
  local callbacks = {
    unpack = function(key, value)
      if type(value) == 'table' and utils.get_array_size(value) == 1 and
        utils.get_table_size(value) == 1 and type(value[1]) ~=
        'table' then
        return key, value[1]
      end
      return key, value
    end,

    process_naked = function(key, value)
      if type(key) == 'number' and type(value) == 'string' then
        return value, opts.default
      end
      return key, value
    end,

    format_key = function(key, value)
      if type(key) == 'string' then
        for _, style in ipairs(opts.format_keys) do
          if style == 'lower' then
            key = key:lower()
          elseif style == 'snake' then
            key = key:gsub('[^%w]+', '_')
          elseif style == 'upper' then
            key = key:upper()
          else
            throw_error('E017', {
              unknown = style,
              styles = { 'lower', 'snake', 'upper' },
            })
          end
        end
      end
      return key, value
    end,

    apply_invert_flag = function(key, value)
      if type(key) == 'string' and key:find(opts.invert_flag) then
        return key:gsub(opts.invert_flag, ''), not value
      end
      return key, value
    end,
  }

  if opts.unpack then
    result = utils.visit_tree(result, callbacks.unpack)
  end

```

```
      if not opts.naked_as_value and opts.defs == false then
        result = utils.visit_tree(result, callbacks.process_naked)
      end

      if opts.format_keys then
        if type(opts.format_keys) ~= 'table' then
          throw_error('E018', { data_type = type(opts.format_keys) })
        end
        result = utils.visit_tree(result, callbacks.format_key)
      end

      if opts.invert_flag then
        result = utils.visit_tree(result, callbacks.apply_invert_flag)
      end

      return result
    end
    result = apply_opts(result, opts)

    log_result('after apply opts', result)

    ---All unknown keys are stored in this table
    local unknown = nil
    if type(opts.defs) == 'table' then
      apply_hooks('before_defs')
      result, unknown = apply_definitions(opts.defs, opts, result, {},
        {}, {}, utils.clone_table(result))
    end

    log_result('after apply_definitions', result)

    apply_hooks()

    if opts.defaults ~= nil and type(opts.defaults) == 'table' then
      utils.merge_tables(result, opts.defaults, false)
    end

    log_result('End result', result)

    if opts.accumulated_result ~= nil and type(opts.accumulated_result) ==
      'table' then
      utils.merge_tables(opts.accumulated_result, result, true)
    end

    ---no_error
    if not opts.no_error and type(unknown) == 'table' and
      utils.get_table_size(unknown) > 0 then
      throw_error('E019', { unknown = visualizers.render(unknown) })
    end
    return result, unknown, raw
  end

  ---
  ---@param defs DefinitionCollection
  ---@param opts? OptionCollection
  local function define(defs, opts)
    return function(kv_string, inner_opts)
      local options

      if inner_opts ~= nil and opts ~= nil then
        options = utils.merge_tables(opts, inner_opts)
      elseif inner_opts ~= nil then
```

```
        options = inner_opts
      elseif opts ~= nil then
        options = opts
      end

      if options == nil then
        options = {}
      end

      options.defs = defs

      return parse(kv_string, options)
    end
  end

  ---@alias KeySpec table<integer|string, string>

  local DefinitionManager = (function()
    ---@class DefinitionManager
    DefinitionManager = {}

    ---@private
    DefinitionManager.__index = DefinitionManager

    ---
    ---@param key string
    ---
    ---@return Definition
    function DefinitionManager:get(key)
      return self.defs[key]
    end

    ---
    ---@param key_spec KeySpec
    ---@param clone? boolean
    ---
    ---@return DefinitionCollection
    function DefinitionManager:include(key_spec, clone)
      local selection = {}
      for key, value in pairs(key_spec) do
        local src
        local dest
        if type(key) == 'number' then
          src = value
          dest = value
        else
          src = key
          dest = value
        end
        if clone then
          selection[dest] = utils.clone_table(self.defs[src])
        else
          selection[dest] = self.defs[src]
        end
      end
      return selection
    end

    ---
    ---@param key_spec KeySpec
    ---@param clone? boolean
    ---
    ---@return DefinitionCollection
    function DefinitionManager:exclude(key_spec, clone)
      local spec = {}
      for key, value in pairs(key_spec) do
        if type(key) == 'number' then
          spec[value] = value
        else
          spec[key] = value
        end
      end

      local selection = {}
      for key, def in pairs(self.defs) do
        if spec[key] == nil then
          if clone then
            selection[key] = utils.clone_table(def)
          else
            selection[key] = def
          end
        end
      end
      return selection
    end

    ---
    ---@param key_selection KeySpec
    function DefinitionManager:parse(kv_string, key_selection)
      return parse(kv_string, { defs = self:include(key_selection) })
    end

    ---
    ---@param key_selection KeySpec
    function DefinitionManager:define(key_selection)
      return define(self:include(key_selection))
    end

    ---@param defs DefinitionCollection
    ---
    ---@return DefinitionManager
    return function(defs)
      local manager = {}

      for key, def in pairs(defs) do
        if def.name ~= nil and type(key) == 'number' then
          defs[def.name] = def
          defs[key] = nil
        end
      end

      setmetatable(manager, DefinitionManager)
      manager.defs = defs
      return manager
    end
  end)()

  ---
  ---A table to store parsed key-value results.
  local result_store = {}

  return {
    new = main,

```

```lua
version = { 0, 15, 0 },

parse = parse,

define = define,

DefinitionManager = DefinitionManager,

---@see default_opts
opts = default_opts,

error_messages = error_messages,

---@see visualizers.render
render = visualizers.render,

---@see visualizers.stringify
stringify = visualizers.stringify,

---@see visualizers.debug
debug = visualizers.debug,

---
---Save a result (a
---table from a previous run of `parse`) under an identifier.
---Therefore, it is not necessary to pollute the global namespace to
---store results for the later usage.
---
---@param identifier string # The identifier under which the result is saved.
---
---@param result table|any # A result to be stored and that was created by the key-value parser.
save = function(identifier, result)
  result_store[identifier] = result
end,

---
---The function `get(identifier): table` retrieves a saved result
---from the result store.
---
---@param identifier string # The identifier under which the result was saved.
---
---@return table|any
get = function(identifier)
  ---if result_store[identifier] == nil then
  ---  throw_error('No stored result was found for the identifier \'' .. identifier .. '\'')
  ---end
  return result_store[identifier]
end,

is = is,

utils = utils,

---
---Exported but intentionally undocumented functions
---

namespace = utils.clone_table(namespace),

---
```

```
    ---This function is used in the documentation.
    ---
    ---@param from string # A key in the namespace table, either `opts`, `hook` or `attrs`.
    print_names = function(from)
      local names = utils.get_table_keys(namespace[from])
      tex.print(table.concat(names, ', '))
    end,

    print_default = function(from, name)
      tex.print(tostring(namespace[from][name]))
    end,

    print_error_messages = function()
      local msgs = namespace.error_messages
      local keys = utils.get_table_keys(namespace.error_messages)
      for _, key in ipairs(keys) do
        local msg = msgs[key]
        ---@type string
        local msg_text
        if type(msg) == 'table' then
          msg_text = msg[1]
        else
          msg_text = msg
        end
        utils.tex_printf('\\item[\\texttt{%s}]: \\texttt{%s}', key,
          msg_text)
      end
    end,

    ---
    ---@param exported_table table
    depublish_functions = function(exported_table)
      local function warn_global_import()
        throw_error('E023')
      end

      exported_table.parse = warn_global_import
      exported_table.define = warn_global_import
      exported_table.save = warn_global_import
      exported_table.get = warn_global_import
    end,
  }

end

return main
```

8.2 luakeys.tex

```
%% luakeys.tex
%% Copyright 2021-2024 Josef Friedrich
%
% This work may be distributed and/or modified under the
% conditions of the LaTeX Project Public License, either version 1.3c
% of this license or (at your option) any later version.
% The latest version of this license is in
%   http://www.latex-project.org/lppl.txt
% and version 1.3c or later is part of all distributions of LaTeX
% version 2008/05/04 or later.
%
% This work has the LPPL maintenance status `maintained'.
%
% The Current Maintainer of this work is Josef Friedrich.
%
% This work consists of the files luakeys.lua, luakeys.sty, luakeys.tex
% luakeys-debug.sty and luakeys-debug.tex.

\directlua{
  if luakeys == nil then
    luakeys = require('luakeys')()
    luakeys.depublish_functions(luakeys)
  end
}
```

8.3 luakeys.sty

```
%% luakeys.sty
%% Copyright 2021-2024 Josef Friedrich
%
% This work may be distributed and/or modified under the
% conditions of the LaTeX Project Public License, either version 1.3c
% of this license or (at your option) any later version.
% The latest version of this license is in
%   http://www.latex-project.org/lppl.txt
% and version 1.3c or later is part of all distributions of LaTeX
% version 2008/05/04 or later.
%
% This work has the LPPL maintenance status `maintained'.
%
% The Current Maintainer of this work is Josef Friedrich.
%
% This work consists of the files luakeys.lua, luakeys.sty, luakeys.tex
% luakeys-debug.sty and luakeys-debug.tex.

\NeedsTeXFormat{LaTeX2e}
\ProvidesPackage{luakeys}[2024/09/29 v0.15.0 Parsing key-value options using Lua.]
\directlua{
  if luakeys == nil then
    luakeys = require('luakeys')()
    luakeys.depublish_functions(luakeys)
  end
}

\def\LuakeysGetPackageOptions{\luaescapestring{\@ptionlist{\@currname.\@currext}}}

\def\LuakeysGetClassOptions{\luaescapestring{\@raw@classoptionslist}}
```

8.4 luakeys-debug.tex

```
%% luakeys-debug.tex
%% Copyright 2021-2024 Josef Friedrich
%
% This work may be distributed and/or modified under the
% conditions of the LaTeX Project Public License, either version 1.3c
% of this license or (at your option) any later version.
% The latest version of this license is in
%   http://www.latex-project.org/lppl.txt
% and version 1.3c or later is part of all distributions of LaTeX
% version 2008/05/04 or later.
%
% This work has the LPPL maintenance status `maintained'.
%
% The Current Maintainer of this work is Josef Friedrich.
%
% This work consists of the files luakeys.lua, luakeys.sty, luakeys.tex
% luakeys-debug.sty and luakeys-debug.tex.

\directlua
{
  luakeys = require('luakeys')()
  if lparse == nil then
    lparse = require('lparse')
  end
}

\def\luakeysdebug%
{%
  \directlua%
  {
    local oarg, marg = lparse.scan('o v')
    local opts
    if oarg then
      opts = luakeys.parse(oarg, { format_keys = { 'snake', 'lower' } })
    end
    local result = luakeys.parse(marg, opts)
    luakeys.debug(result)
    tex.print(
      '{' ..
        '\string\\tt' ..
        '\string\\parindent=0pt' ..
        luakeys.stringify(result, true) ..
      '}'
    )
  }%
}
```

8.5 luakeys-debug.sty

```
%% luakeys-debug.sty
%% Copyright 2021-2024 Josef Friedrich
%
% This work may be distributed and/or modified under the
% conditions of the LaTeX Project Public License, either version 1.3c
% of this license or (at your option) any later version.
% The latest version of this license is in
%   http://www.latex-project.org/lppl.txt
% and version 1.3c or later is part of all distributions of LaTeX
% version 2008/05/04 or later.
%
% This work has the LPPL maintenance status `maintained'.
%
% The Current Maintainer of this work is Josef Friedrich.
%
% This work consists of the files luakeys.lua, luakeys.sty, luakeys.tex
% luakeys-debug.sty and luakeys-debug.tex.

\NeedsTeXFormat{LaTeX2e}
\ProvidesPackage{luakeys-debug}[2024/09/29 v0.15.0 Debug package for luakeys.]

\input luakeys-debug.tex
```