Functions in Lua

R. Иерусалимский

Pontifícia Universidade Católica
do Rio de Janeiro

anonymous functions

function values

closures

first-class functions

lambdas

What does “function” mean?

It means several things...

Functions are First-Class Values

- Functions are values.
  - or, there are values that represent functions.
- These values can be stored in variables and data structures.
- They can be passed as arguments to and returned by other functions (*higher-order functions*).
- They can be called anywhere in a program.

Functions can be Nested

- We can define functions inside other functions.
  - recursively

```
function foo (x)
  function p (y)
    print(y)
  end
  p(2*x)
end
```

There are Anonymous Functions

- We can write a function without giving a name to it.
- Syntactically, we can write a function as an *expression* in the language.

```
add = (function (x,y) return x+y end)
```

Nested Functions have Lexical Scoping

- A function can access local variables from its enclosing functions.
- A function can *escape* from its enclosing function (e.g., by being returned) and still access those variables.

```
function makecounter (n)
  return function (d)
           n = n + d
           return n
         end
 end
```

```
c = makecounter(10)
print(c(1))   --> 11
print(c(3))   --> 14
```

Properties Somewhat Independent

- C has functions as first-class values, but no nesting.
- Lisp (original) has functions as first-class values and anonymous functions, but no lexical scoping.
- Pascal has lexical scoping, but functions are not first-class values.
- Python 2 and Java have lexical scoping, but only for values.
- *Blocks* in Ruby and Smalltalk are anonymous with lexical scoping, but they are not first-class values.

How Lua uses functions to achieve its goals

What are the Goals?

- Portability
- Simplicity
- Small size
- Scripting

Portability

- Runs on most platforms we ever heard of:
  - Posix (Linux, BSD, etc.), OS X, Windows, Android, iOS, Arduino, Raspberry Pi, Symbian, Nintendo DS, PSP, PS3, IBM z/OS, etc.
  - written in ANSI C.
- Runs inside OS kernels.
  - FreeBSD, Linux
- Written in ANSI C, as a *free-standing application.*

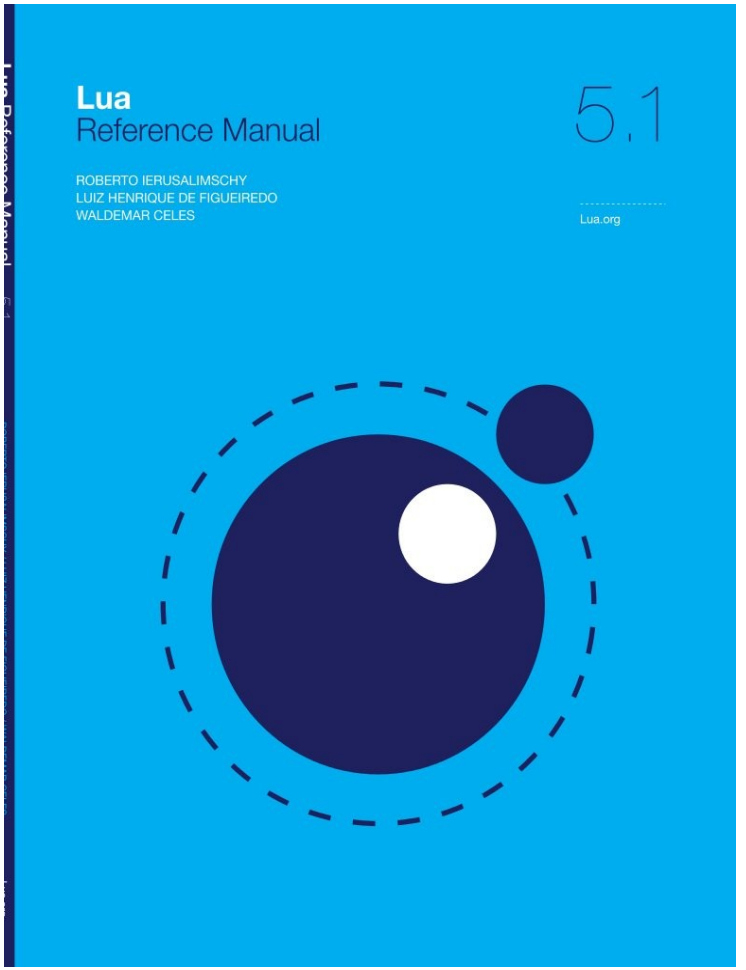
Simplicity

Reference manual with less than 100 pages (proxy for complexity).

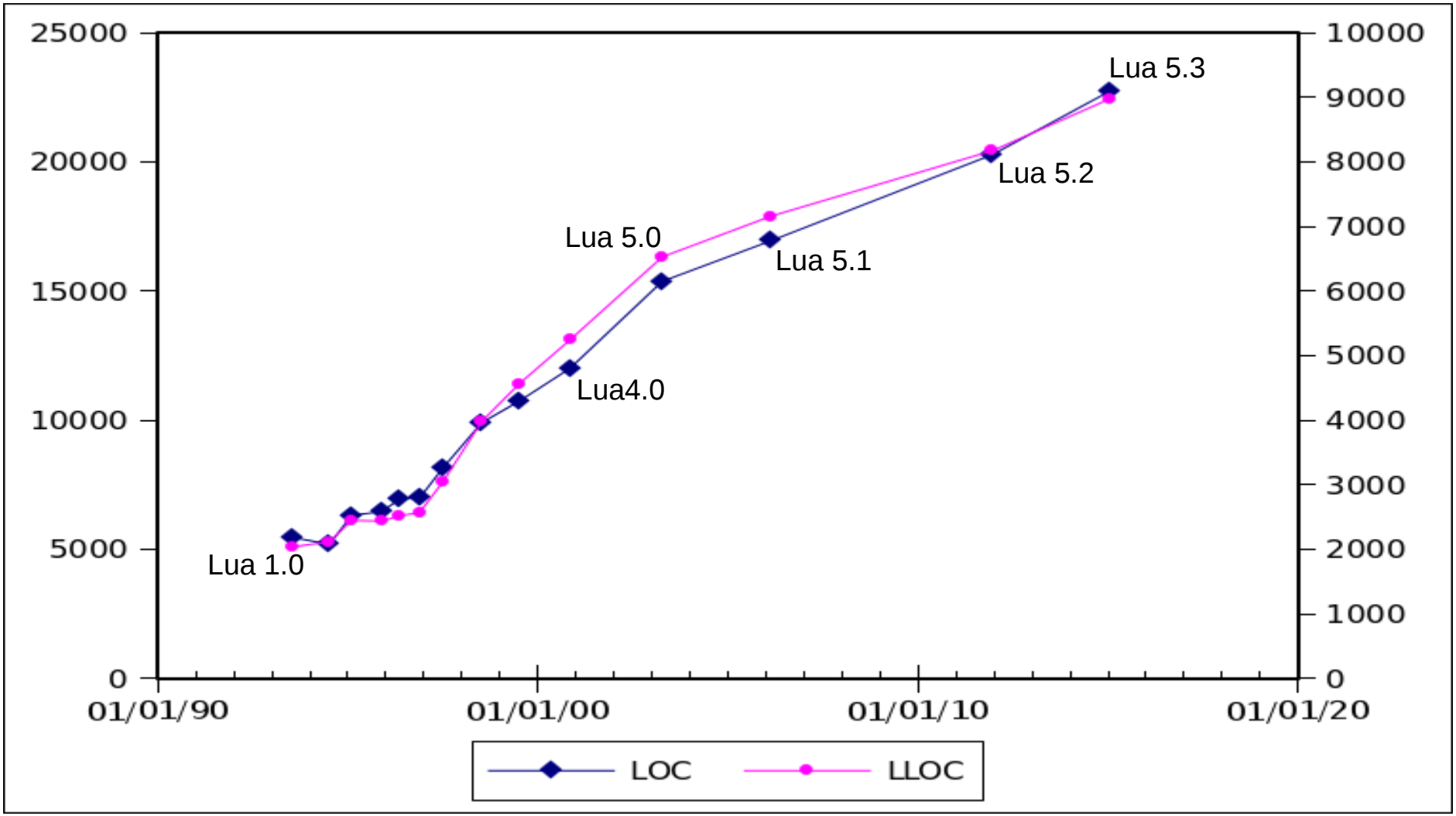
Documents the language, the libraries, and the C API.

(spine)

Lua Reference Manual 5.1 ROBERTO IERUSALIMSCHY / LUIZ HENRIQUE DE FIGUEIREDO / WALDEMAR CELES Lua.org



Size


25000
20000
15000
10000
5000
0
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
01/01/90
01/01/00
01/01/10
01/01/20
Lua 1.0
Lua4.0
Lua 5.0
Lua 5.1
Lua 5.2
Lua 5.3
LOC
LLOC

Scripting

- Scripting language x dynamic language
  - scripting emphasizes inter-language communication.
- Program written in two languages.
  - a scripting language and a system language
- System language implements the hard parts of the application.
  - algorithms, data structures
  - little change
- Scripting *glues* together the hard parts.
  - flexible, easy to change

Lua and Scripting

- Lua is implemented as a library.
- Lua has been designed for scripting.
- Good for *embedding* and *extending.*
- Embedded in C/C++, Java, Fortran, C#, Perl, Ruby, Python, etc.

How Lua uses functions to achieve its goals

Modules

- Tables populated with functions

```
local math = require "math"
print(math.sqrt(10))
```

- Several facilities come for free
  - submodules
  - local names

```
local m = require "math"
print(m.sqrt(20))
local f = m.sqrt
print(f(10))
```

Modules

- Lexical scoping (for local definitions)
- Pros
  - needs no new features
  - easy to interface with other languages
  - flexible
- Cons
  - not as good as “the real thing” (regarding syntax)
  - too dynamic (?)

Eval

- Hallmark of dynamic languages.
- Lua offers a “compile” function instead.

```
function eval (code)
   -- compiles source 'code' and
   -- executes the result
   return load(code)()
end
```

```
function load (code)
   -- creates an anonymous function
   -- with the given body
   return eval("return function () " ..
                  code .. " end")
end
```

Load

- Clearly separates compilation from execution.
- `load` is a pure function.
- It is easier to do `eval` from `load` than the reverse.
- Any code always runs inside some function.
  - we can declare local variables, which naturally work like `static` variables for the functions inside the chunk.
  - chunks can return values.

Exception Handling

- All done through two functions, `pcall` and `error`

```
try {
  <block/throw>
}
catch (err) {
  <exception code>
}
```

```
local ok, err = pcall(function ()
  <block/error>
end)
if not ok then
  <exception code>
end
```

Exception Handling

- Anonymous functions with lexical scoping
- Pros
  - simple semantics
  - no extra syntax
  - simple to interface with other languages
- Cons
  - verbose
  - body cannot return/break
  - `try` is not cost-free

Iterators

- Old style:

```
local inv = {}
table.foreach(t, function (k, v)
  inf[v] = k
end)
```

- New style:

```
for w in allwords(file) do
  print(w)
end
```

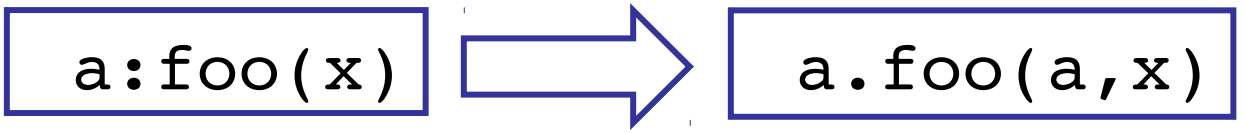
```
function allwords (file)
  local line = io.read(file)
  local pos = 1
  return function ()
    while line do
      local w, e = string.match(line, "(%w+)()", pos)
      if w then
        pos = e
        return w
      else
        line = io.read(file)
        pos = 1
      end
    end
    return nil
  end
end
```

Iterators

- Anonymous functions (for old style), lexical scoping
- Pros
  - easy to interface with other languages
- Cons
  - cannot traverse nil
  - not so simple as explained

Objects

- first-class functions + tables ≈ objects
- syntactical sugar for methods
  - handles *self*




```
function a:foo (x)
  ...
end
```

```
a.foo = function (self,x)
  ...
end
```

Objects

- Pros
  - flexible
  - easy to interface with other languages
  - clear semantics
  - needs few new features
- Cons
  - may need some work to get started (DIY)
  - no standard model (DIY)

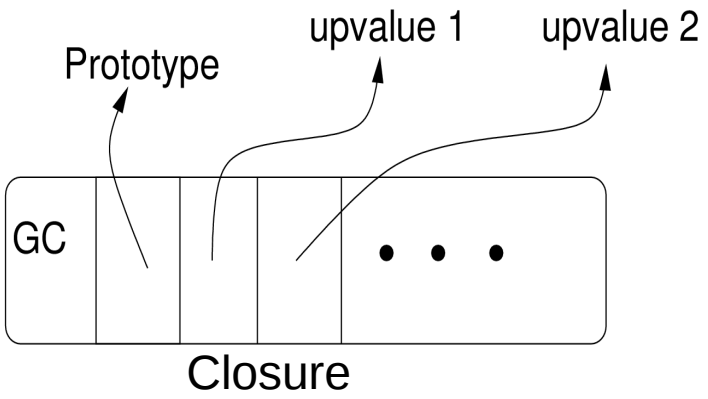
The Lua-C API

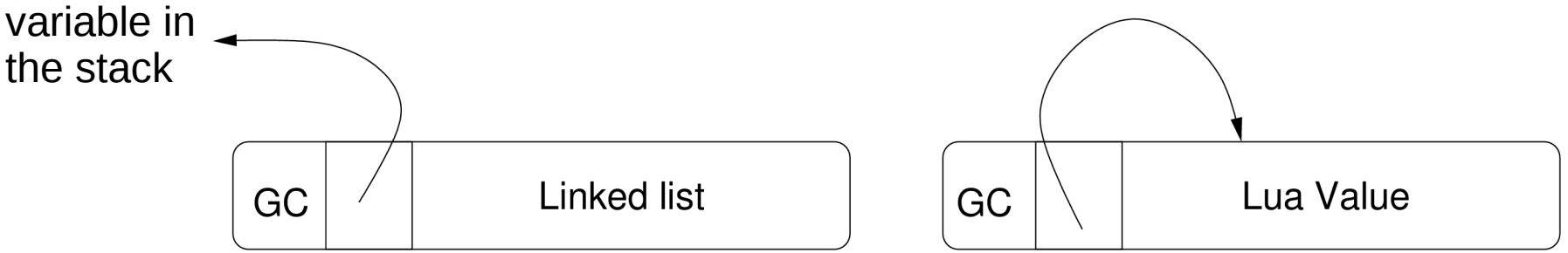
- Functions are constructs found in most languages, wich compatible basic semantics.
- Constructions based on functions are easier to translate between different languages.
- Modules, OO programming, and iterators need no extra features in the Lua-C API.
  - all done with standard mechanisms for tables and functions.
- Exception handling and `load` go the opposite way: primitives in the API, exported to Lua.

Implementation

- Based on *closures.*
- A closure represents the code of a function plus the environment where the function was defined.
- Lua uses *upvalues* to represent the environment, one for each external variable used by the function.
- Zero cost when not used.
  - variables live on the stack.

Basic data structures

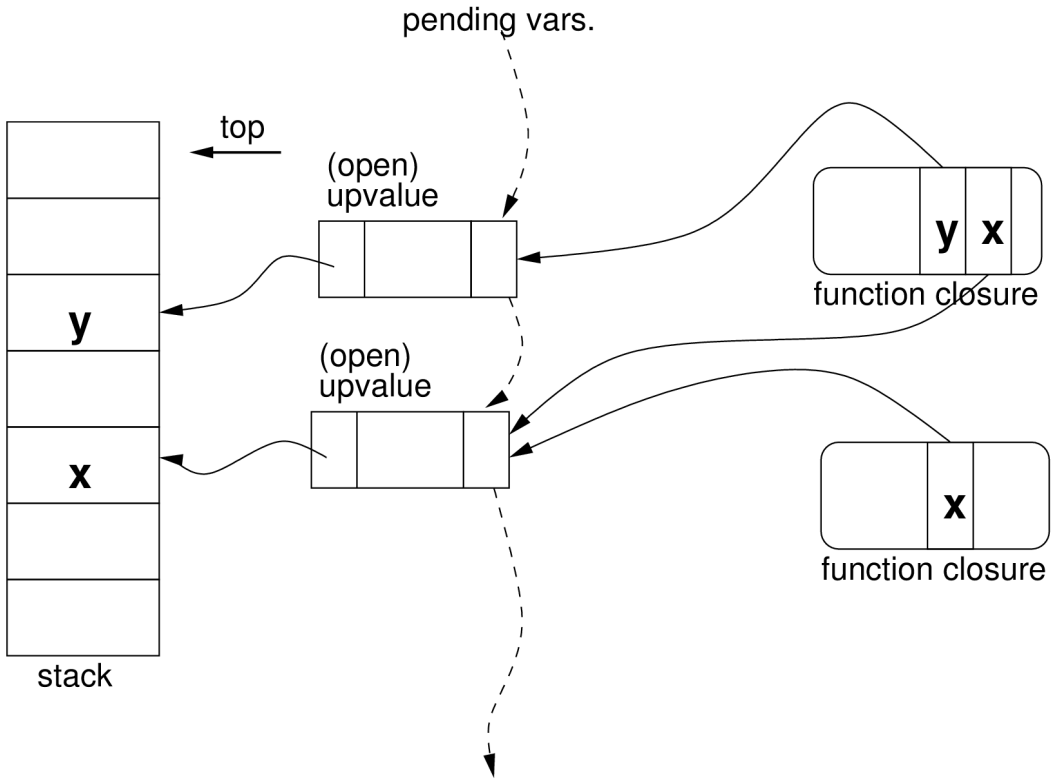




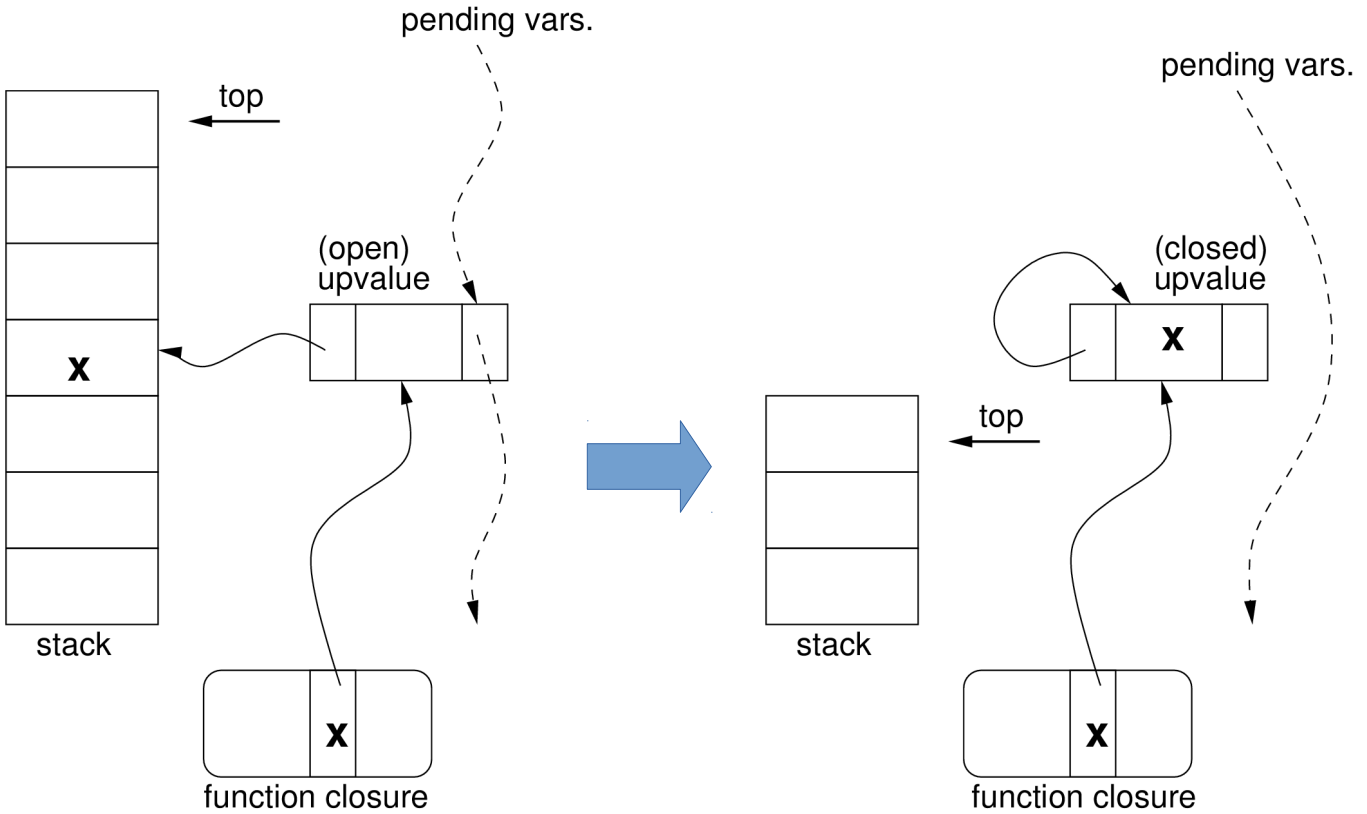
a) open upvalue

b) closed upvalue

List of open upvalues (for unicity)



Closing an upvalue

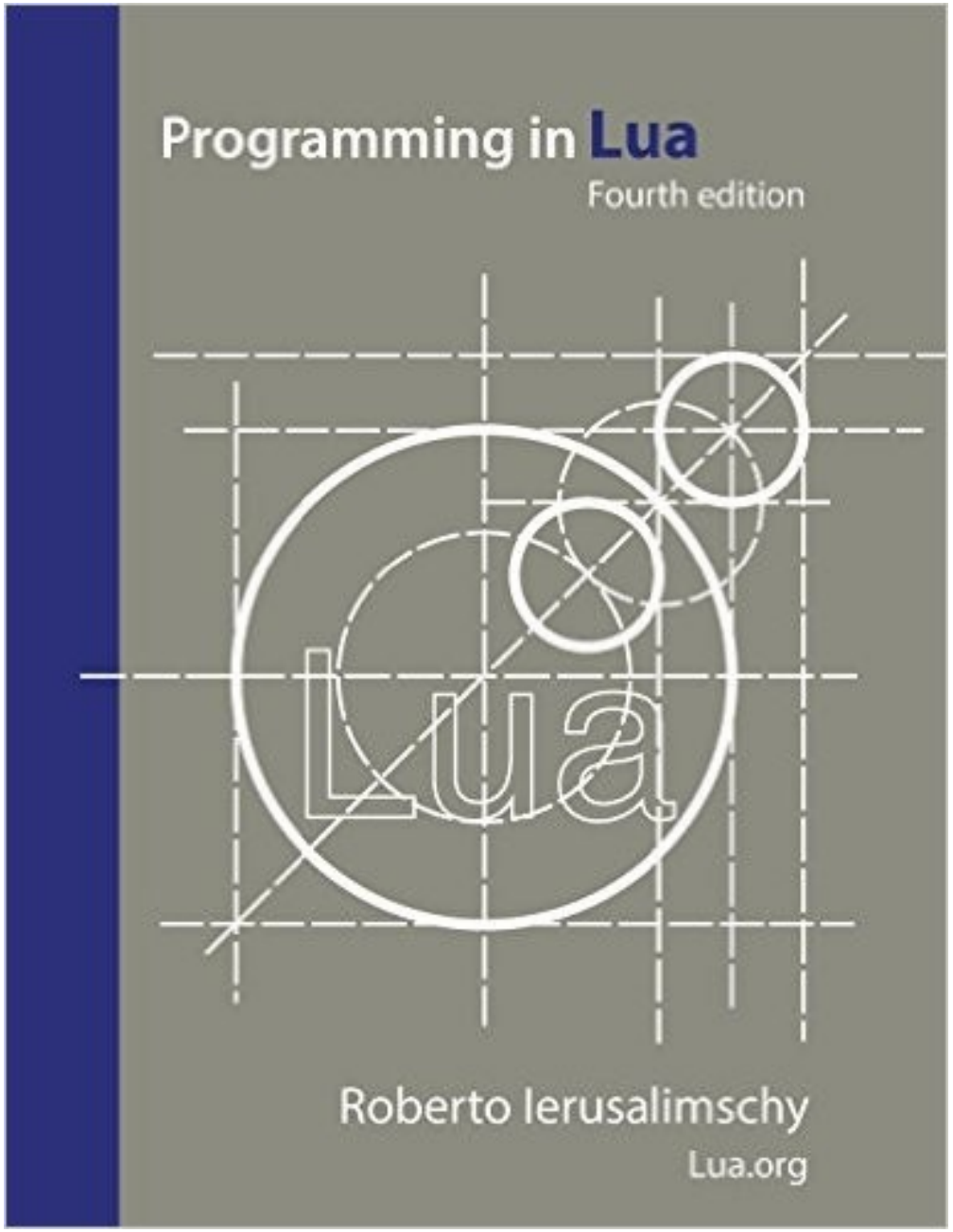


Several Details...

- One-pass compiler.
- Safe for space.
- Uses flattening for nesting.
- List of open upvalues is limited by program syntax.
- A closure may point to upvalues in different stacks.

Final Remarks

- Lua is not only about tables.
- Like with tables, Lua itself uses functions for several important constructs in the language.
- In Lua, the use of constructors based on first-class functions greatly helps to make the C API general.


Programming in Lua
Fourth edition
Lua
Roberto Ierusalimschy
Lua.org