Functions in Lua

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What about Lua?

A simple, dynamic, imperative language, with tables, coroutines, and functions.


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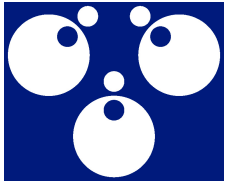


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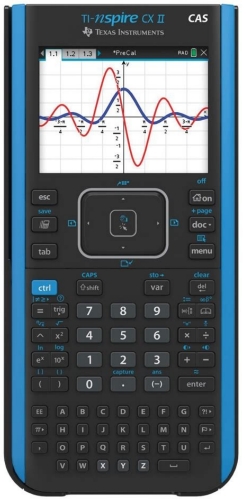
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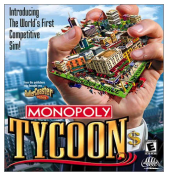
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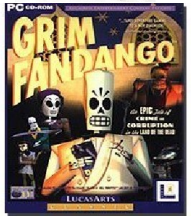
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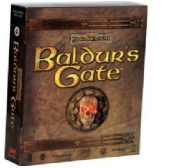
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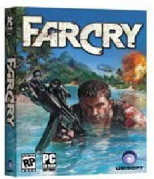
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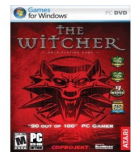
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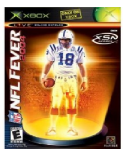
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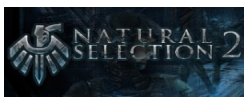
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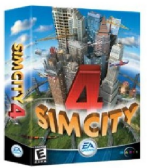
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What are the Goals?

- 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.
- Runs inside OS kernels: FreeBSD, Linux
- Runs directly on the bare metal, without an OS: NodeMCU ESP8266

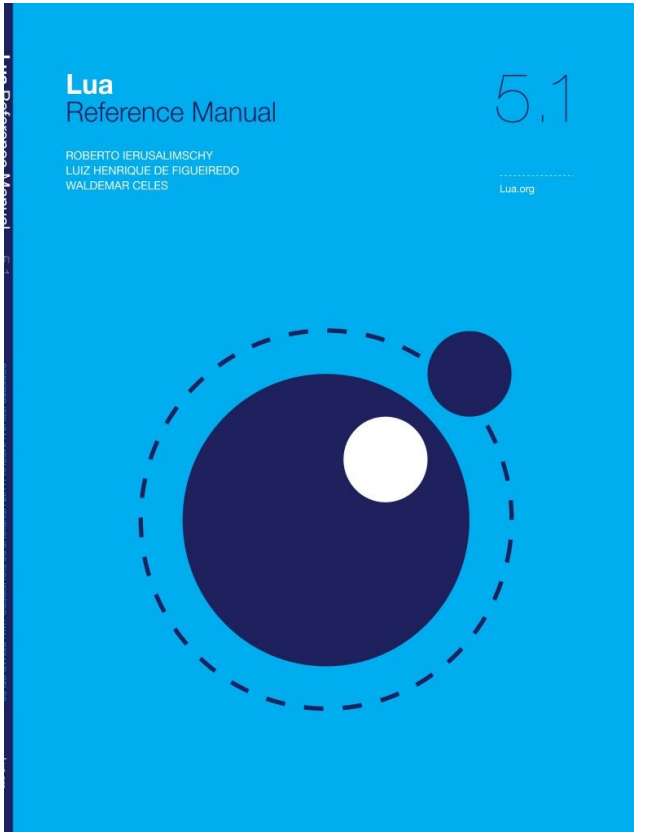
Simplicity

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



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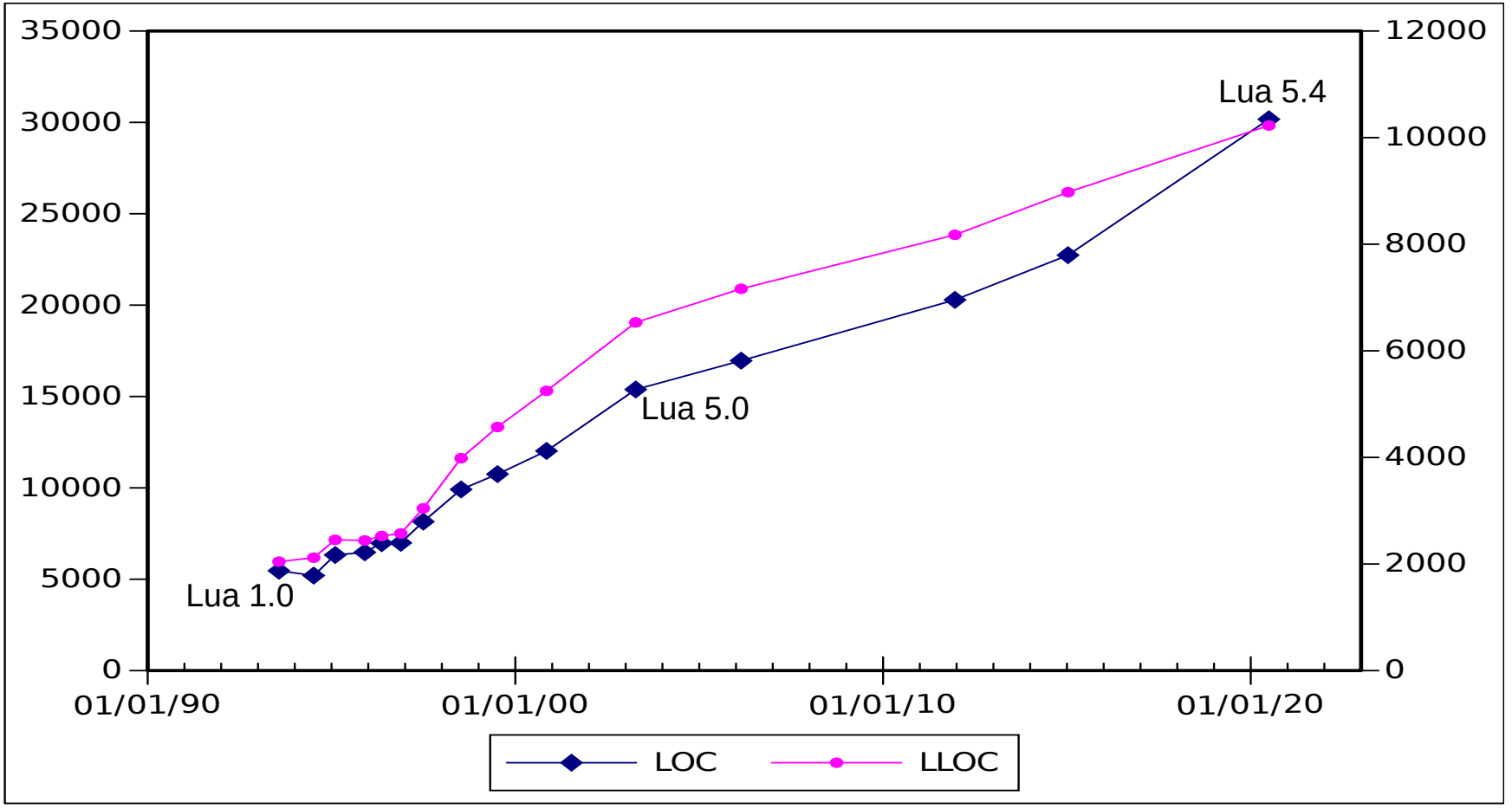
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Lua 1.0
Lua 5.0
Lua 5.4
LOC
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Scripting

- Scripting language is not a synonym for dynamic language.
- Program written in two languages.
- System language implements the hard parts of the application.
- Scripting *glues* together the hard parts.

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.

Tables

- Only data structure in Lua
- Associative arrays
  - maps keys of any type to values of any type
- Arrays: tables with integer keys
- Records: tables with field names (strings) as keys: `t.x` is sugar for `t["x"]`

Coroutines

- Collaborative threads
- Equivalent to one-shot continuations
  - we can write `call/1cc` with them

Functions

anonymous functions

function values

first-class functions

closures

lambdas

higher-order functions

What does “function” mean?

- Functions are first-class values.
- Functions can be nested.
- Nested functions have lexical scoping (with mutable variables).
- There are anonymous functions.

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.

Properties Somewhat Independent

- *Blocks* in Ruby and Smalltalk are anonymous with lexical scoping, but they are not first-class values.
- Java has lexical scoping, but only for values.
- C++ needs manual “assigment conversion” for mutable external variables.

How Lua uses functions to achieve its goals

Simplicity/Small size

- All functions are anonymous.
- Syntax sugar for several typical constructs.

```
function foo (...) ... end
```

```
foo = function (...) ... end
```

```
local function foo (...) ... end
```

```
local foo;
foo = function (...) ... end
```

```
function foo (...) ... end
```

```
foo = function (...) ... end
```

```
local function foo (...) ... end
```

```
local foo;
foo = function (...) ... end
```

```
local foo = function (...) ... end
```

Eval

- `eval` is a hallmark of dynamic languages.
- Lua offers a `load` function instead, which returns a function.

```
local f = load(“print(10)”)
f()  --> 10
f()  --> 10
```

Load

- Clearly separates compilation from execution.
- `load` is a pure function.
- Any code always runs inside some function.
- It is easier to do `eval` from `load` than the reverse.

Modules

- Tables populated with functions

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

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

Modules

- Syntactically, a module is a function that creates its table.
- Local variables are private to the module.
- the expression `require “math”` finds an adequate file, then loads and executes it; the returned value is the module table.

Exception Handling

- All done through two functions, `pcall` and `error`.
- `pcall` calls a function in *protected mode*, catching any error.
- `error` *raises* an error. (It calls the continuation of the inner enclosing `pcall`.)

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

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

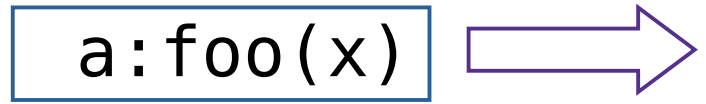
Exception Handling

- simple semantics
- no extra syntax
- simple to interface with other languages

Objects

- first-class functions + tables ≈ objects
- syntactic sugar for methods (colon syntax)

```
a:foo(x)
```



```
a.foo(a,x)
```

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

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

Objects

- Flexible
- easy to interface with other languages
- clear semantics
- Few new concepts: a *method* is just a regular function

The Lua-C API

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.

The Lua-C API

- Modules and OO programming 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.

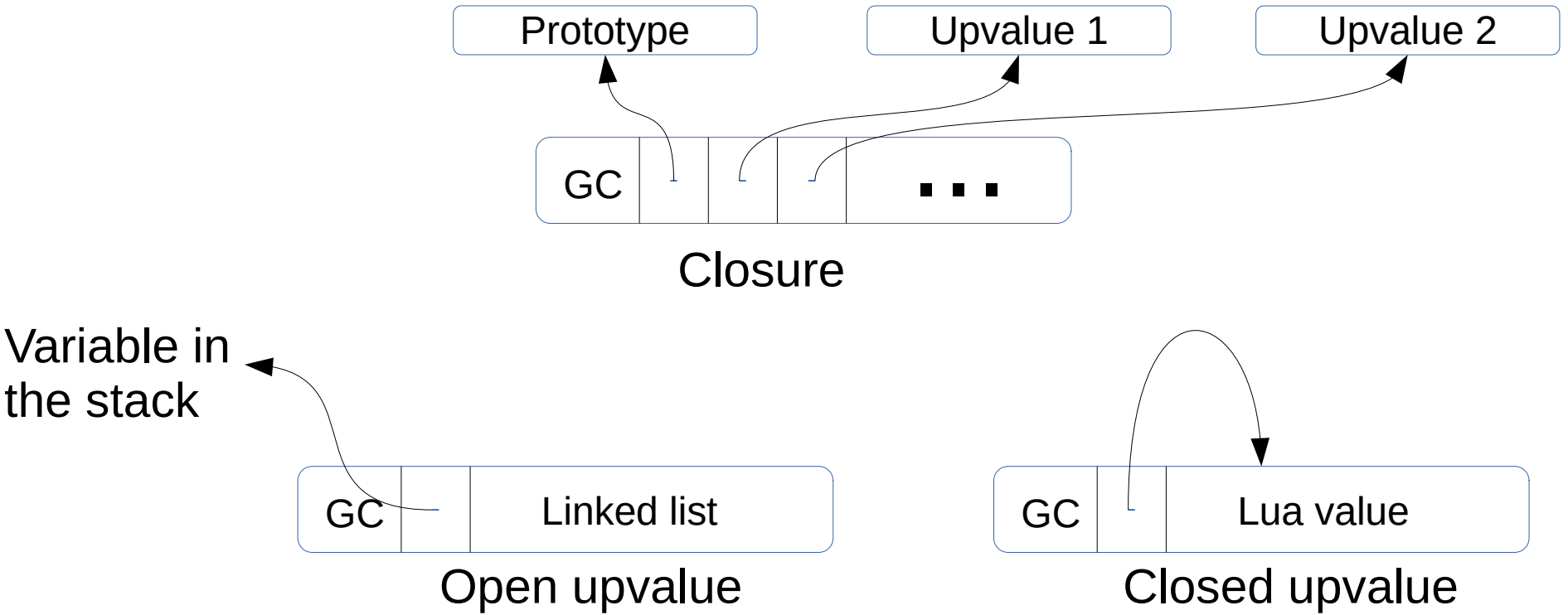
Implementation Requirements

- One-pass compiler.
- Safe for space.
- No assigment conversion.
- A function may use variables from several different stacks (coroutines).

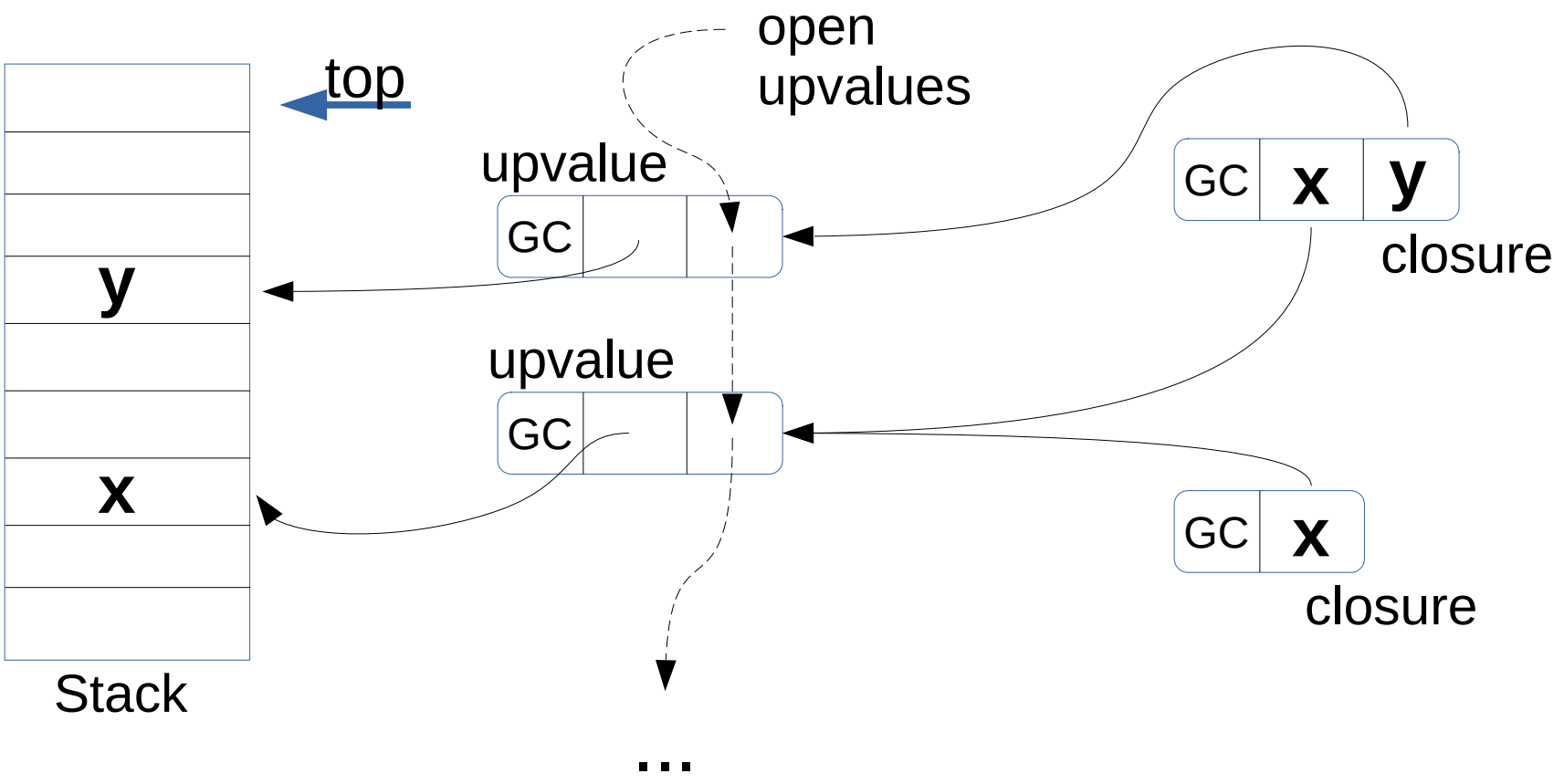
Implementation

- Geared towards imperative languages.
- Zero cost when not used: All local variables live on the stack.
- Lua uses *upvalues* to intermeditate the access to external variables.

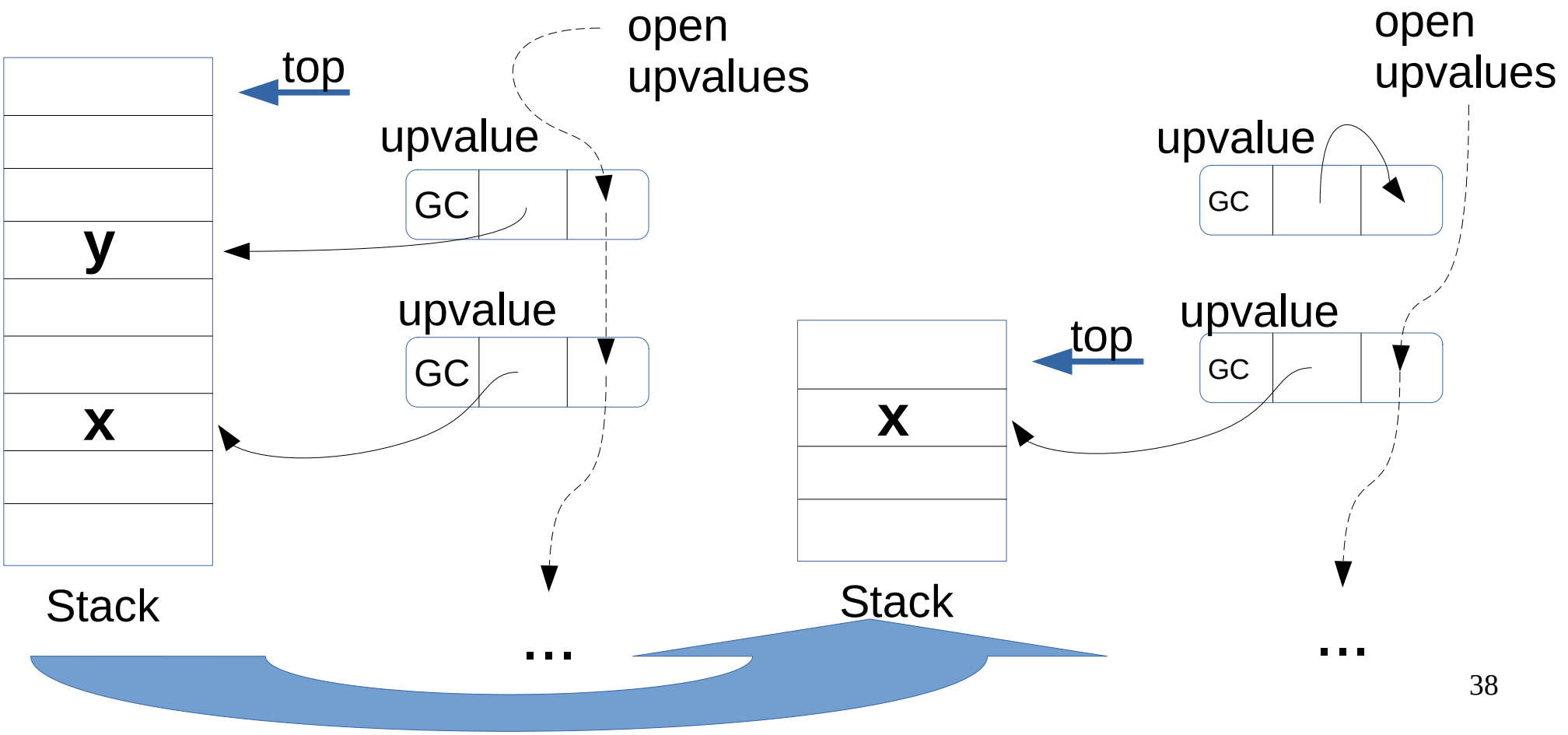
Basic data structures



List of open upvalues (for unicity)



Closing an upvalue - Closing a scope

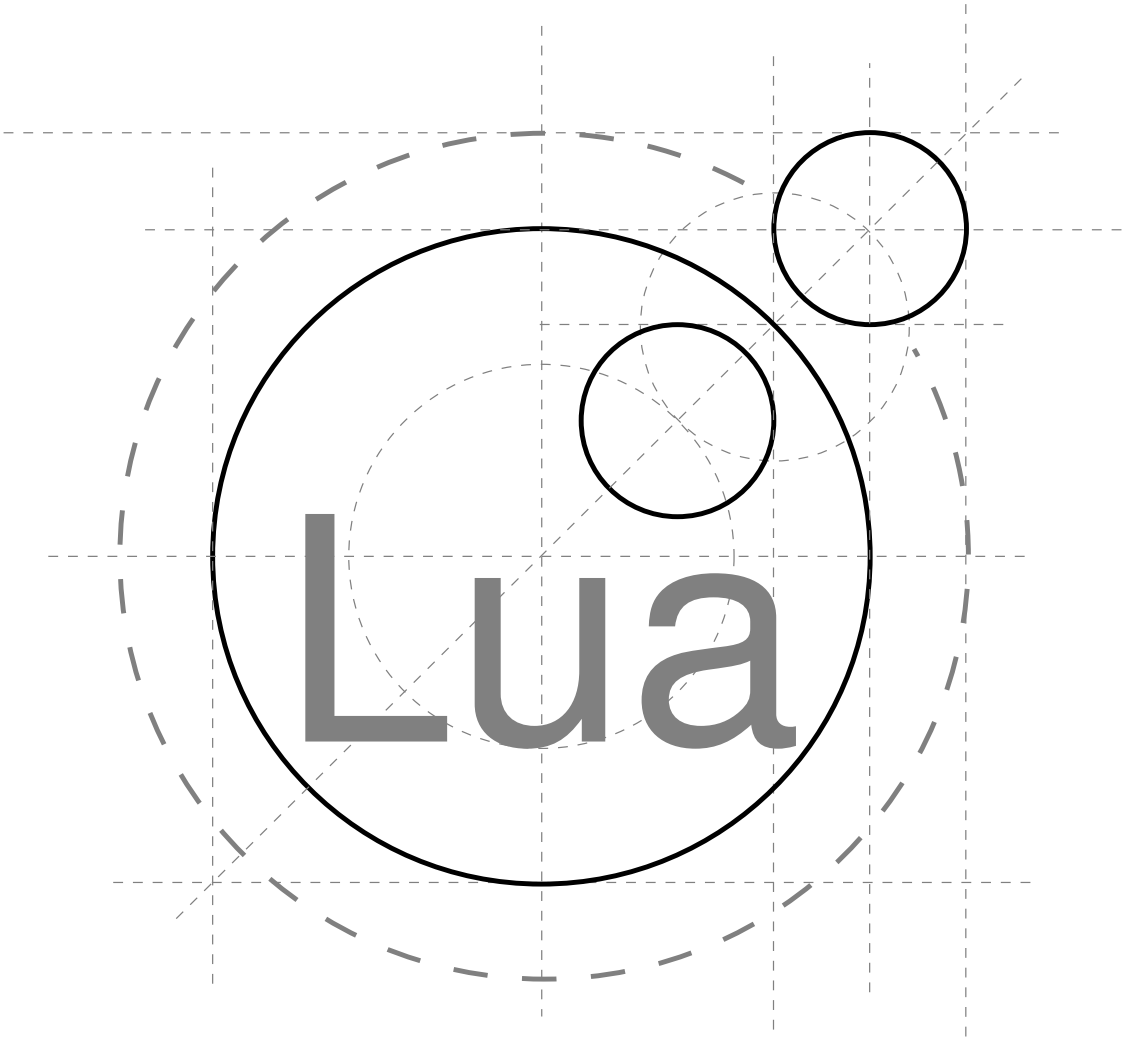


Several Details...

- Uses flattening for nesting.
- List of open upvalues is limited by program syntax.
- Unicity needed for mutability.
- A closure may point to upvalues in different stacks.

Final Remarks

- First-class functions are a key ingredient for programming in Lua.
- Lua itself uses functions for several basic constructs in the language.
- In Lua, the use of constructors based on first-class functions greatly helps to make the C API general.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