

Declarative Internal DSLs in Lua

A Game-Changing Experience

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Internal Declarative DSL in Lua

```
namespace:method "title"  
{  
  data = "here";  
}
```

...Without sugar

```
_G["namespace"]:method(  
    "title"  
) ({  
    ["data"] = "here";  
})
```

Naïve implementation

```
namespace = { }  
  
namespace.method = function(self, name)  
  return function(data)  
    -- ...do something  
    -- ...with name and data  
  end  
end
```

Hyphotetical UI description language

```
ui:dialog "alert"  
{  
  ui:label "message";  
  ui:button "OK"  
  {  
    on_click = function(self)  
      self:close()  
    end;  
  };  
}
```

UI description language "implementation", I

```
function ui:label(title)
  return function(data)
    return GUI.Label:new(title, data)
  end
end

function ui:button(title)
  return function(data)
    return GUI.Button:new(title, data)
  end
end
```

UI description language "implementation", II

```
function ui:dialog(title)
  return function(data)
    local dialog = GUI.Dialog:new(title)
    for i = 1, #data do
      dialog:add_child(data)
    end
    return dialog
  end
end
```


Ad-hoc approach

- + Easy to code simple stuff

But:

- Easily grows out of control
- Difficult to reuse
- Hard to handle errors
- Hard to add new output targets

Practical example: HTTP handler

```
api:url "/reverse"
{
  doc:description [[String reverser]]
  [[
    Takes a string and reverses it.
  ]];
  api:input { data:string "text" };
  api:output
  {
    data:node "result" { data:string "reversed" };
  };
  handler = function(param)
    return { reversed = param.text:reverse() }
  end;
}
```

What do we want to get from that description?

- ▶ **HTTP request handler itself**, with:
 - ▶ Input validation
 - ▶ Multi-format output serialization (JSON, XML, ...)
 - ▶ Handler code static checks (globals, ...)
- ▶ **Documentation**
- ▶ Low-level networking **client code**
- ▶ Smoke **tests**

Request handler: input validation

```
local handler = function(checker, param)
  return
  {
    text = checker:string(param, "text");
  }
end
```

```
INPUT_LOADERS["/reverse.xml"] = handler
INPUT_LOADERS["/reverse.json"] = handler
```

Request handler: output serialization

```
local build_formatter = function(fmt)
  return fmt:node("nil", "result")
  {
    fmt:attribute("reversed");
  }
end
```

```
OUTPUT["/reverse.xml"] = build_formatter(
  make_xml_formatter_builder()
):commit()
```

```
OUTPUT["/reverse.json"] = build_formatter(
  make_json_formatter_builder()
):commit()
```

Request handler: the handler itself

- Handler code is checked for access to illegal globals.*
- Legal globals are aliased to locals at the top.*
- Necessary require() calls are added automatically.*

```
local handler = function(param)
  return
  {
    reversed = param.text:reverse();
  }
end
```

```
HANDLERS["/reverse.xml"] = handler;
HANDLERS["/reverse.json"] = handler;
```

Documentation

/reverse.{xml, json}: String reverser

Takes a string and reverses it.

IN

?text=STRING

OUT

XML:

```
<result reversed="STRING" />
```

JSON:

```
{ "result": { "reversed": "STRING" } }
```

Smoke tests

```
test:case "/reverse.xml:smoke.ok" (function()  
  local reply = assert(http.GET(  
    TEST_HOST .. "/reverse.xml?text=Foo")  
  ))  
  assert(type(reply.result) == "table")  
  assert(type(reply.result.reversed) == "string")  
end)
```


Too complicated for ad-hoc solution!

TODO: Spaghetti cat image goes here

The "proper" solution?

- ▶ Should be easy to add a new target.
- ▶ Should be reusable.
- ▶ Should have nicer error reporting.

The process

- ▶ Load data.
- ▶ Validate correctness.
- ▶ Generate output.

Let's recap how our data looks like

```
api:url "/reverse"
{
  doc:description [[String reverser]]
  [[
    Takes a string and reverses it.
  ]]
  api:input { data:string "text" };
  api:output
  {
    data:node "result" { data:string "reversed" };
  };
  handler = function(param)
    return { reversed = param.text:reverse() }
  end;
}
```

Surprise! It's a tree!

```
{ id = "api:url", name = "/reverse";
  { id = "doc:description", name = "String reverser";
    text = "Takes a string and reverses it.";
  };
  { id = "api:input";
    { id = "data:string", name = "text" };
  };
  { id = "api:output";
    { id = "data:node", name = "result";
      { id = "data:string", name = "reversed" };
    };
    handler = function(param)
      return { reversed = param.text:reverse() }
    end;
  };
}
```

We need a loader that does this: (I)

```
namespace:method "title"  
{  
  data = "here";  
}  
  
⇒  
  
{  
  id = "namespace:method";  
  name = "title";  
  data = "here";  
}
```

We need a loader that does this: (II)

```
namespace:method "title"    ⇒    {  
                                id = "namespace:method";  
                                name = "title";  
                                }
```

We need a loader that does this: (III)

```
namespace:method  
{  
  data = "here";  
}
```

```
⇒ {  
  id = "namespace:method";  
  data = "here";  
}
```


We need a loader that does this: (IV)

```
namespace:method "title"  
[[  
  text  
]]
```

⇒

```
{  
  id = "namespace:method";  
  name = "title";  
  text = [[  
    text  
  ]];  
}
```

We need a loader that does this: (V)

```
namespace:method "title" (function()  
  -- do something  
end)
```

⇒

```
{  
  id = "namespace:method";  
  name = "title";  
  handler = function()  
    -- do something  
  end;  
}
```

...And adds some debugging info for nice error messages:

```
-- my_dsl.lua:
42: namespace:method "title"
43: {
44:   data = "here";
45: }
⇒
{
  id = "namespace:method";
  name = "title";
  data = "here";
  file_ = "my_dsl.lua";
  line_ = 42;
}
```

Nested nodes should just... nest:

```
namespace:method "title"  
{  
  data = "here";  
  foo:bar "baz_1";  
  foo:bar "baz_2";  
}
```

⇒

```
{  
  id = "namespace:method";  
  name = "title";  
  data = "here";  
  
  { id = "foo:bar", name = "baz_1" };  
  { id = "foo:bar", name = "baz_2" };  
}
```

Notes on data structure:

- ▶ Use unique objects instead of string keys to avoid name clashes.
- ▶ Or you may store user-supplied "data" in a separate key.

Metatable magic, I

```
_G["namespace"]:method(  
    "title"  
) ({  
    ["data"] = "here";  
})  
  
setmetatable(  
    _G, -- actually, the sandbox  
        -- environment for DSL code  
    MAGIC_ENV_MT  
)
```

Metatable magic, II

```
_G["namespace"]:method(  
    "title"  
) ({  
    ["data"] = "here";  
})  
  
MAGIC_ENV_MT.__index = function(t, k)  
    return setmetatable(  
        { },  
        MAGIC_PROXY_MT  
    )  
end
```

Metatable magic, III

```
_G["namespace"]:method(  
    "title"  
    ) ({  
    ["data"] = "here";  
    })  
  
MAGIC_PROXY_MT.__call = function(self, title)  
    self.name = title  
    return function(data)  
        data.name = self.name  
        return data  
    end  
end
```


Things are somewhat more complex: (I)

- ▶ You must detect "syntax sugar" forms (text, handler)...
 - ▶ ...just watch out for types, nothing complicated.
- ▶ You have to care for single-call forms (name-only, data-only)...
 - ▶ ...store all proxies after first call
 - ▶ and extract data from what's left after DSL code is executed.

Things are somewhat more complex: (II)

- ▶ Error handling not shown...
 - ▶ ...it is mostly argument type validation at this stage,
 - ▶ but global environment protection aka strict mode is advisable.
- ▶ Debug info gathering not shown...
 - ▶ ...just call `debug.getinfo()` in `__call`.
- ▶ You *should* keep order of top-level nodes...
 - ▶ ...make a list of them at the "name" call stage.

Format-agnostic DSL loader

Loads DSL data to the in-memory tree.

- ▶ *Reusability*: Works for any conforming DSL without modifications.
- ▶ *Output targets*: N/A.
- ▶ *Error reporting*: Does what it can, but mostly that is behind its scope.

Bonus DSL syntax construct

```
namespace:method "title"  
  : modifier "text"  
  : another { modifier_data = true }  
{  
  data = "here";  
}
```

On subnodes: DSL vs plain tables, I

What is better?

```
foo:bar "name"  
{  
  subnode =  
  {  
    key = "value";  
  };  
}
```

...Or...

```
foo:bar "name"  
{  
  foo:subnode  
  {  
    key = "value";  
  };  
}
```

On subnodes: DSL vs plain tables, II

It depends on the nature of the data.

- ▶ If subnode is a *genuine tree node*, use `foo:bar.foo:subnode` DSL subnodes.
- ▶ But for *parameters* of the tree node, even when they are stored in a sub-table, use plain old `foo:bar.subnode` tables.
- ▶ When unsure, pick whichever is easier for tree traversal in each case.

One third done

- ✓ Load data.
- ▶ Validate correctness.
- ▶ Generate output.

Validation and generation

- ▶ Trading speed for convenience (but not so much).
- ▶ Traversing the tree (or rather forest) once for validation pass and once for each output target.

Tree traversal (hat tip to Metalua)

```
namespace:method "title" { -- 3rd
  data = "here";
  foo:bar "baz_1"; -- 1st
  foo:bar "baz_2"; -- 2nd
}
--
local walkers = { up = { }, down = { } }
walkers.down["foo:bar"] = function(walkers, node, parent)
  assert(node.name == "baz_1" or node.name == "baz_2")
end
walkers.down["namespace:method"] = function(
  walkers, node, parent
)
  assert(node.name == "title" and #node.data > 0)
end
--
walk_tree(dsl_data, walkers)
```

Tree traversal process

- ▶ Bidirectional, depth-first: down, then up.
- ▶ If a handler for a given `node.id` is not found, it is considered a "do nothing" function. Traversal continues.
- ▶ If down handler returns "break" string, traversal of subtree is aborted.
- ▶ Knowing a node parent is useful.

Tree traversal hints

- ▶ Store state in walker object.
- ▶ Set metatables on `up` and `/` or `down` for extra power.
- ▶ In complex cases gather data in `down`, act in `up`.
- ▶ In even more complex cases break in `down`, and run a custom traversal on the node subtree.

Validation

```
walkers.up["foo:bar"] = function(walkers, node)
  walkers:ensure(
    "check condition A", predicate_A(node),
    node.file_, node.line_
  )
end

walk_tree(dsl_data, walkers)

if not walkers:good() then
  error(
    "data validation failed: "
    .. walkers:message()
  )
end
```

Validation notes

- ▶ *Don't skip implementing it.* Even poor validation is better than none.
- ▶ *But don't overdo as well.* Depending on the nature of the language, overly strict validator may harm usability. Keep optional things optional, and be flexible (just) enough in what input you accept.
- ▶ *Do validation in a separate pass.* In output generation assume data to be valid and do not clutter the code with redundant checks.
- ▶ *Accumulate all errors before failing.* This will improve usability. But don't forget to teach users that errors at the end of the list may be bogus.
- ▶ *Report full stack of wrong nodes.* From the failed node up to the root.

Almost there

- ✓ Load data.
- ✓ Validate correctness.
- ▶ Generate output.

Output generation, I

```
walkers.down["namespace:method"] = function(walkers, node)
  walkers:cat
    [[<method name=]] (xml_escape(node.name)) [[>]]
end
```

```
walkers.up["foo:bar"] = function(walkers, node)
  walkers:cat
    [[<bar name=]] (xml_escape(node.name)) [[ />]]
end
```

```
walkers.up["namespace:method"] = function(walkers, node)
  walkers:cat [[</method>]]
end
```

Output generation, II

```
function walkers.cat(walkers, v)
  walkers.buf[#walkers.buf + 1] = tostring(v)
  return walkers.cat
end
```

```
function walkers.concat(walkers)
  return table.concat(walkers)
end
```

```
walk_tree(dsl_data, walkers)
```

```
output:write(walkers:concat())
```


Output generation notes

- ▶ *One tree walker per target.* Otherwise make sure that your trusty old cheese grater is still sharp.
- ▶ *Use string ropes or write directly to file.* Or face GC overhead.
- ▶ *You may generate run-time objects instead of strings.* But off-line generation is much neater.
- ▶ *Think!* A lot of output generation problems are easier than they look.

Validation and output generation

...By means of data tree traversal.

- ▶ *Reusability*: High. Almost everything that you have to write is business-logic. No low-level boilerplate code is visible.
- ▶ *Output targets*: Conforming targets may be added without changing any of existing code.
- ▶ *Error reporting*: You have everything you need to provide good error reports to user.

We're done with DSL handling

- ✓ Load data.
- ✓ Validate correctness.
- ✓ Generate output.

Where do we use internal DSLs ourselves?

Most prominent cases:

- ▶ A HTTP webservice API DSL (which we just discussed).
- ▶ A config file format DSL family.
- ▶ A SQL DB structure DSL.
- ▶ Visual Business Logic Editor DSL family.

A config file format DSL family: node description language

```
types:up "cfg:existing_path" (function(self, info, value)
  local _ =
    self:ensure_equals(
      "unexpected type", type(value), "string"
    ):good()
  and self:ensure(
    "path string must not be empty", value ~= ""
  ):good()
  and self:ensure(
    "path must exist", lfs.attributes(value)
  )
end)
```

A config file format DSL family: config description language

Controlled by the node description language.

```
cfg:node "my_tool"  
{  
  cfg:existing_path "data_path";  
}
```

A config file format DSL family: the config data itself

The data itself is the usual automagic table hierarchy.

```
my_tool.data_path = "path/to/file.bin"
```

A config file format DSL family: output targets

- ▶ Data loader and validator.
- ▶ Documentation.

A SQL DB structure DSL

```
sql:table "countries"  
{  
  sql:primary_key "id";  
  sql:string "title" { 256 };  
  --  
  sql:unique_key "title" { "title" };  
}
```

A SQL DB structure DSL: output targets

- ▶ Initial DB schema SQL code.
- ▶ DB schema patches (semiautomated so far).
- ▶ Full-blown backoffice web-UI for data management.
- ▶ Documentation.

The Logic Editor DSL family: high-level data schema DSL

Human-friendly concepts, describing data tree structure and transformation rules:

```
lang:enum "fruit" {  
    "fruit.orange", "fruit.apple", "fruit.banana";  
  
    render:js [[Fruits]] {  
        [[#{1}]];  
        { [[Orange]] }, { [[Apple]] }, { [[Banana]] };  
    };  
  
    render:lua {  
        [[#{1}]];  
        { [[FRUIT.ORANGE]] }, { [[FRUIT.APPLE]] },  
        { [[FRUIT.BANANA]] };  
    };  
}
```

The Logic Editor DSL family: low-level data schema DSL

Machine-friendly concepts, generated from high-level DSL:

```
node:variant "fruit" {  
  "fruit.orange", "fruit.apple", "fruit.banana";  
  render:js [[Fruits]] { [[#{1}]] };  
  render:lua { [[#{1}]] }; }
```

```
node:literal "fruit.orange" {  
  render:js { [[Orange]] };  
  render:lua { [[FRUIT.ORANGE]] }; }
```

```
node:literal "fruit.apple" {  
  render:js { [[Apple]] };  
  render:lua { [[FRUIT.APPLE]] }; }
```

```
node:literal "fruit.banana" {  
  render:js { [[Banana]] };  
  render:lua { [[FRUIT.BANANA]] }; }
```

The Logic Editor DSL family: output targets

- ▶ From high-level DSL:
 - ▶ low-level DSL;
 - ▶ schema docs (to be implemented).
- ▶ From low-level DSL:
 - ▶ schema-specific visual Editor UI;
 - ▶ data validators;
 - ▶ data-to-code generator;
 - ▶ data upgrade code stubs to handle schema changes.

Why game-changing?

- ▶ Before:
 - ▶ DSL is something exotic, hard to maintain.
 - ▶ Not much declarative code in codebase except a few special places.
 - ▶ All declarative code in code-base totally non-reusable ad-hoc lumps of spaghetti.
 - ▶ Code readability suffers, bugs thrive.
- ▶ Now:
 - ▶ DSLs are much easier to write and reuse.
 - ▶ At least 2/3 of the new code is written in DSL of one kind or another. (But we heavily combine declarative DSL code with Lua functions embedded in it.)
 - ▶ Code much more readable, less bugs in generated code.
- ▶ In future:
 - ▶ A DSL to define DSLs!

Questions?

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