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

```lua
namespace = { }

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

Hypothetical 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

```lua
-- 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!

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";
}
```

$\Rightarrow$

```
{
  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)

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

⇒

```lua
{
  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 "dow" { -- day of week
  "dow.mon", "dow.tue", "dow.wed", "dow.thu",
  "dow.fri", "dow.sat", "dow.sun";
  render:js [[Weekday]] {
    { [[Monday]] }, { [[Tuesday]] }, { [[Wednesday]] },
    { [[Thursday]] }, { [[Friday]] }, { [[Saturday]] },
    { [[Sunday]] };
  };
  render:lua { -- Matching os.date() format.
    { [[2]] }, { [[3]] }, { [[4]] }, -- MO, TU, WE
    { [[5]] }, { [[6]] }, { [[7]] }, -- TH, FR, SA
    { [[1]] }; -- SU
  };
}
```

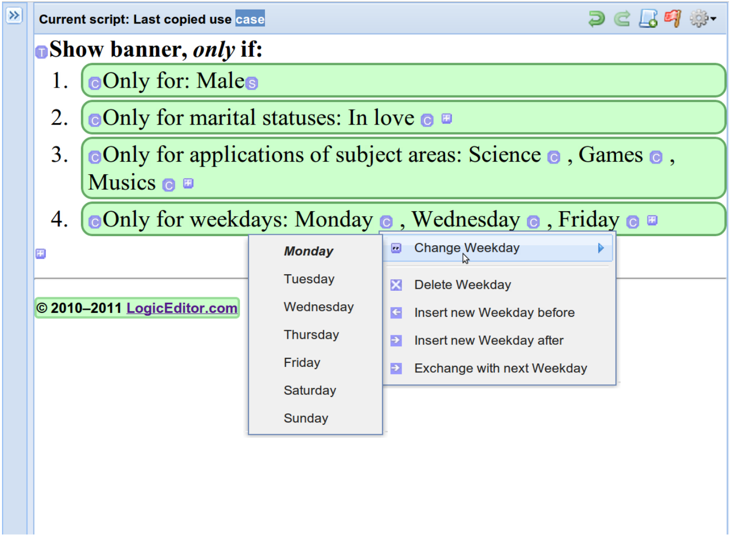
The Logic Editor DSL family: low-level data schema DSL

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

```
node:variant "dow" {
  "dow.mon", "dow.tue", "dow.wed", "dow.thu",
  "dow.fri", "dow.sat", "dow.sun";
  render:js [[Weekday]] { [[#{1}]] };
  render:lua { [[#{1}]] }; }

node:literal "dow.mon" {
  render:js { [[Monday]] };
  render:lua { [[2]] }; }
node:literal "dow.tue" {
  render:js { [[Tuesday]] };
  render:lua { [[3]] }; }
-- ...
```

The Logic Editor DSL family: visual DSL



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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