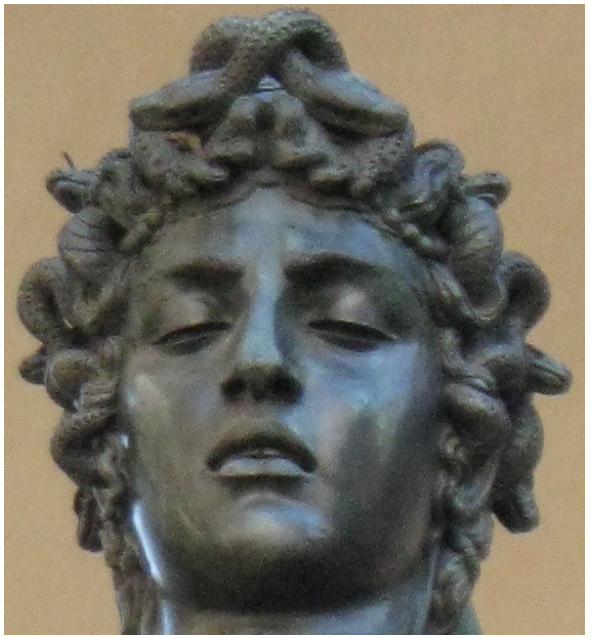
The Medusa compiler

A Lua tool for highly interactive ebooks

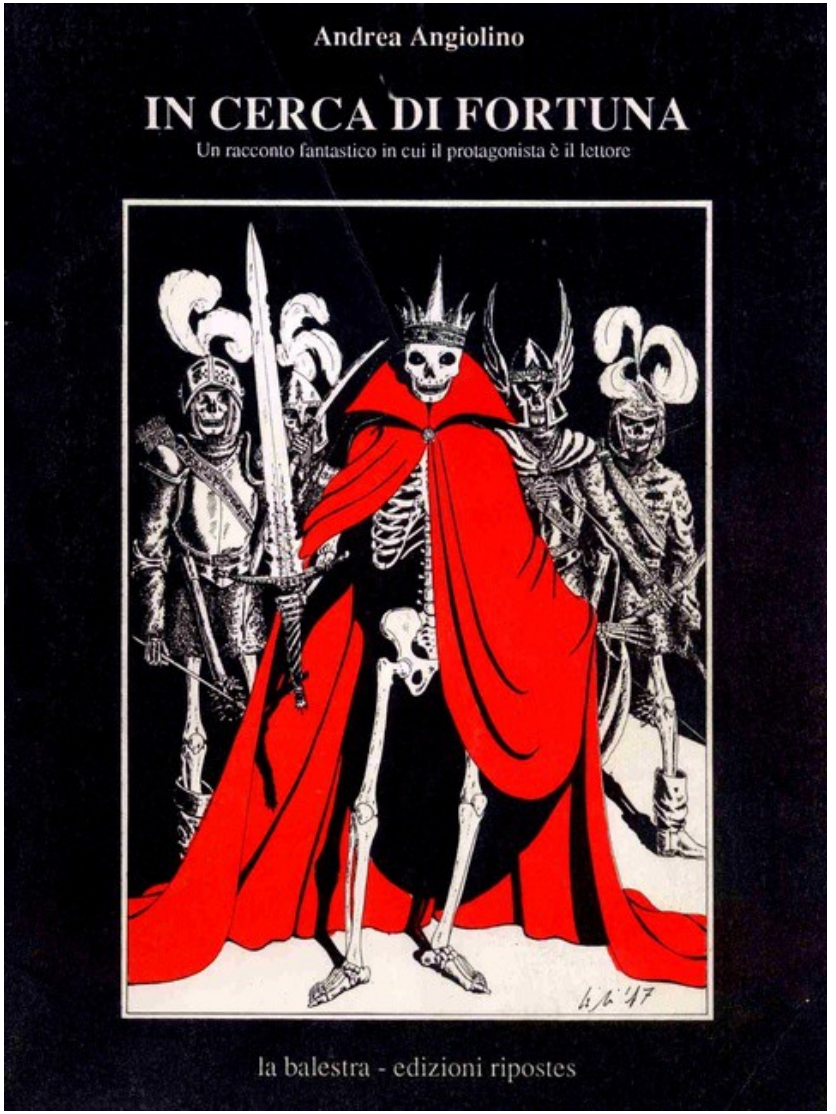


Enrico Colombini <erix@erix.it> (freelance author)

Lua workshop 2014, September 13-14, Moscow

Old ‘gamebooks’

- 1970s-1980s
  (not the first ones)
- Printed on paper
- Simple choices

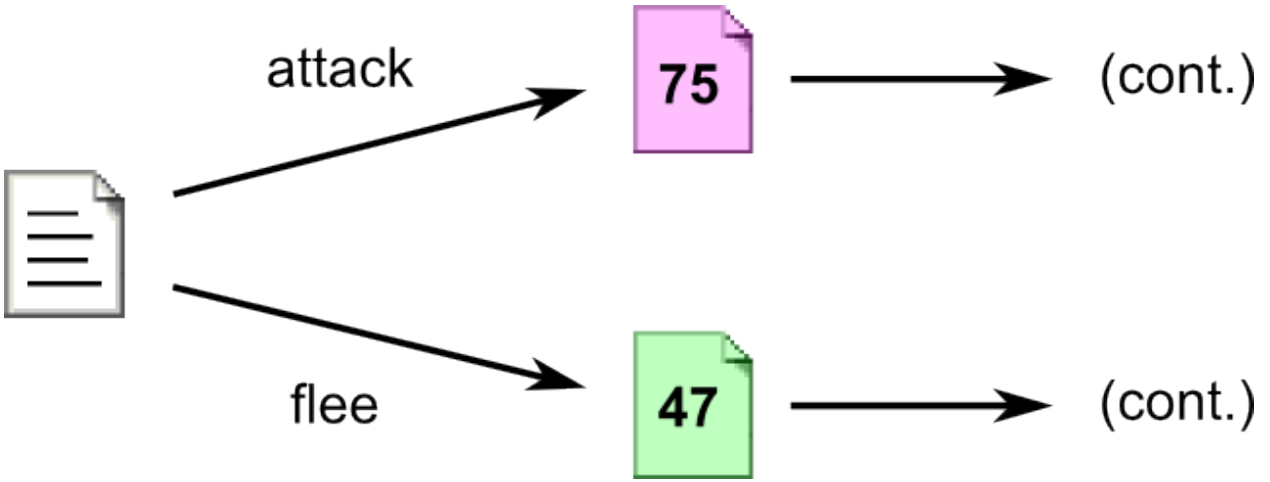


Branches in gamebooks

- “The werewolf is getting nearer”

  - Shoot a silver arrow (go to 75).

  - Flee as fast as you can (go to 47).

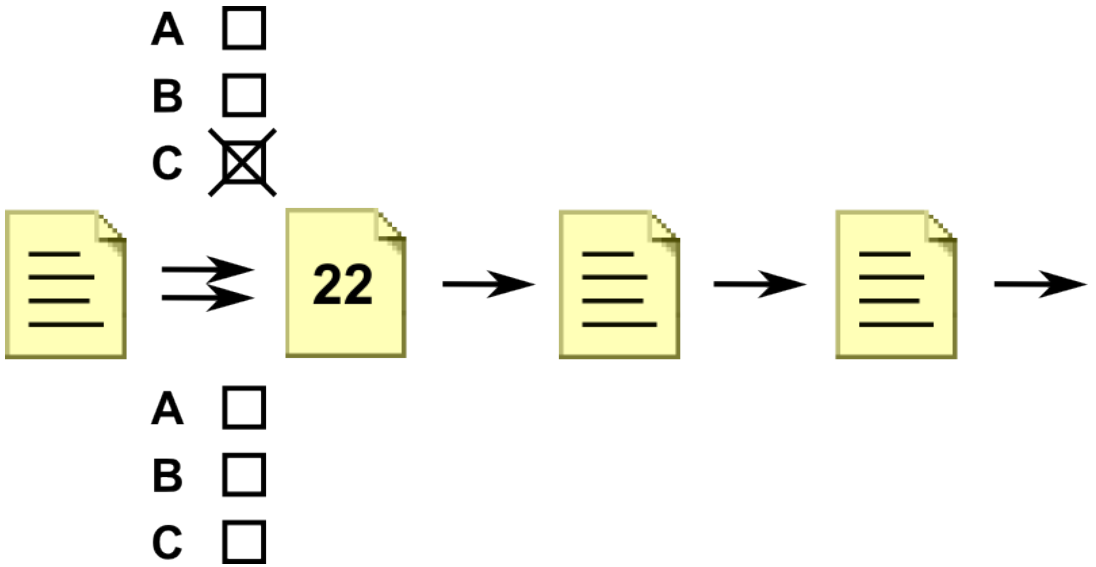


Variables in gamebooks

- “There is only a rusty piece of metal here”

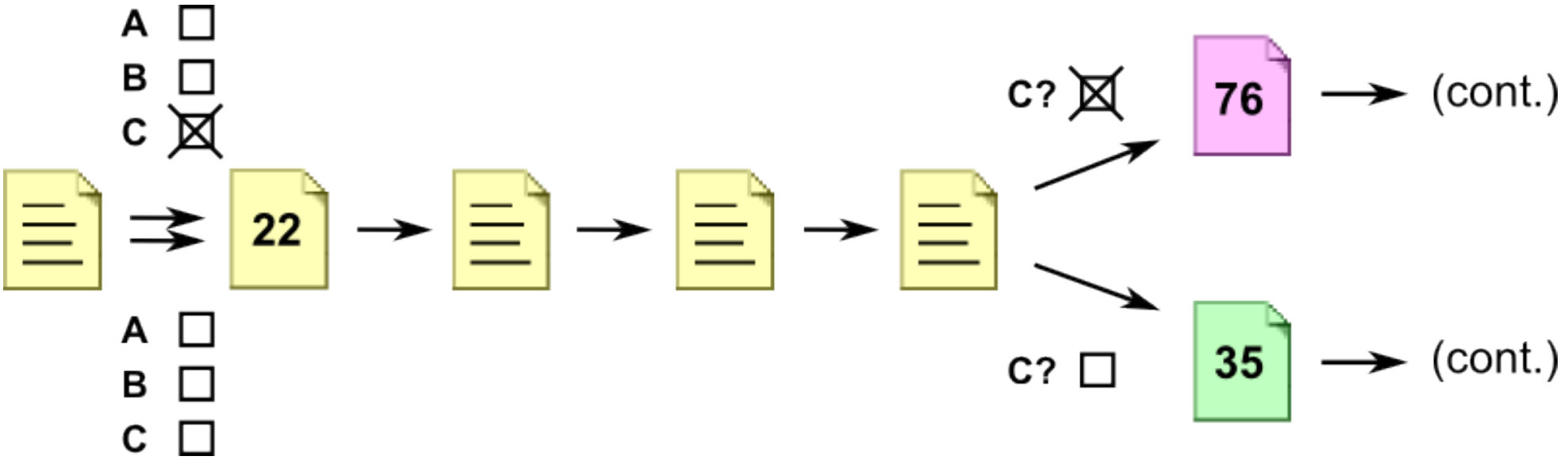
  - Pick it up (tick checkbox ‘C’, go to 22).

  - Leave it here (go to 22).



Memory in gamebooks

- Pen and paper are used to store information
- The human reader is the run-time processor

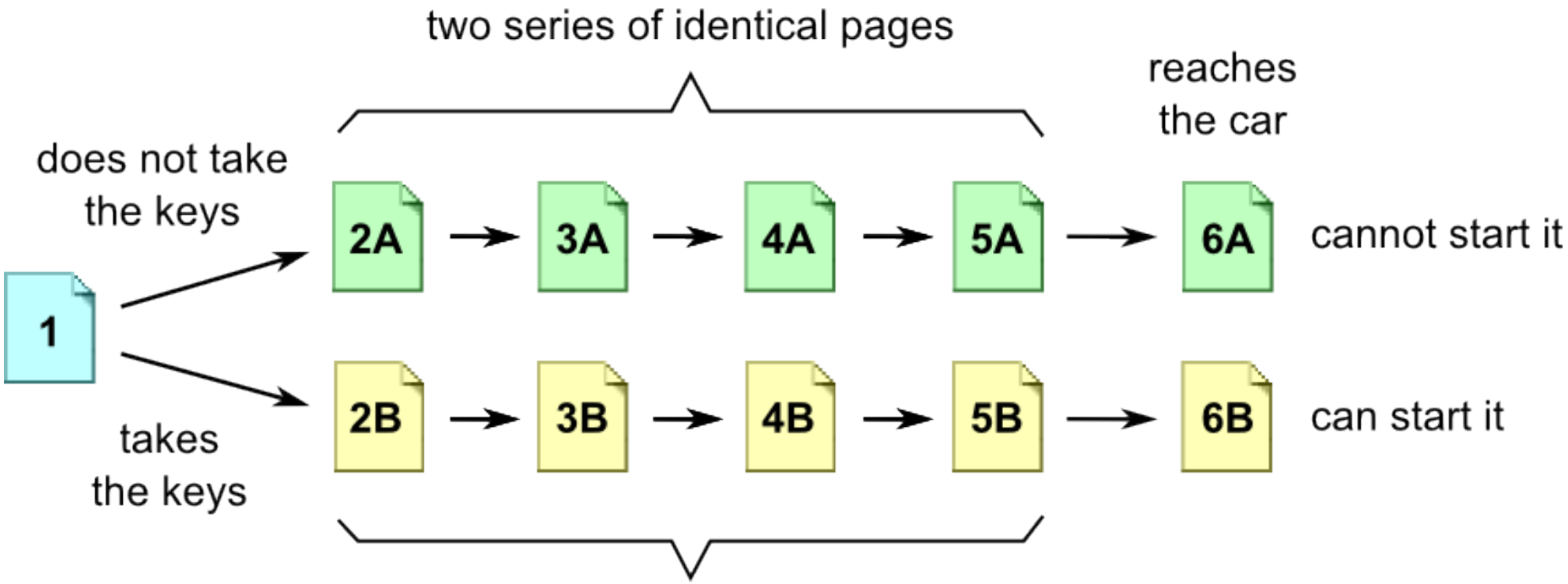


Interactive ebooks

- We have hyperlinks, but...
- No (portable) runtime language
- No way to save variables
- No external storage, processing
- Only remembers the current page
- Immutable set of ‘printed’ pages
- What can we do?

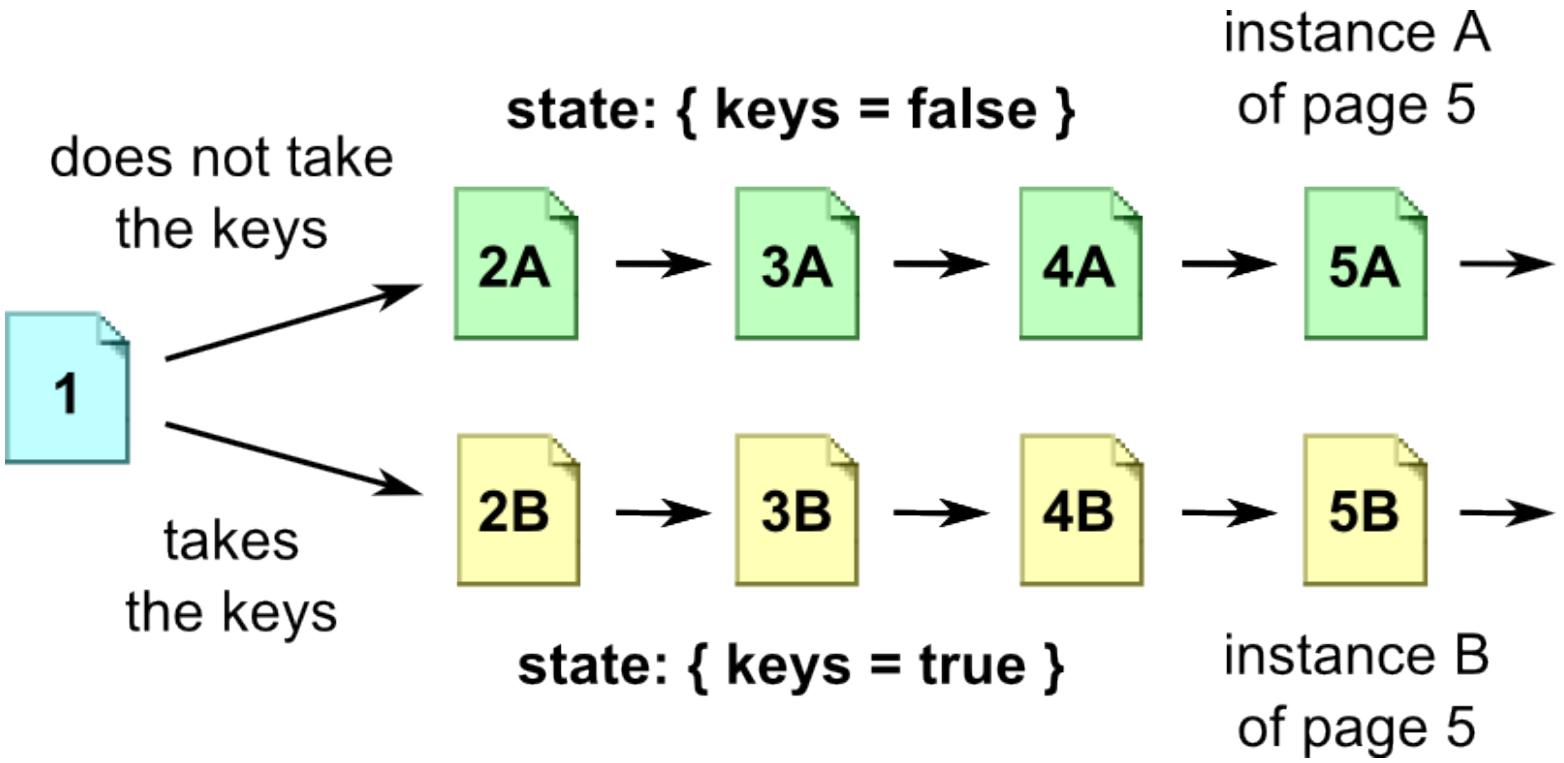
Memory in an ebook

- A boolean can be stored by duplicating pages
- Each branch represents a different state



Source page, instance pages

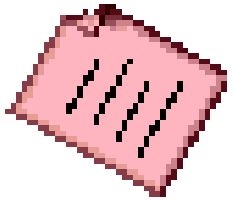
- Each instance page ‘contains’ its state
- Instance page contents can be the same



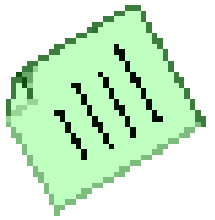
Implications

- Multiple ‘vars’ allow complex behaviour
- A simple bookmark ‘saves’ the whole state
- The human reader is not aware of the state

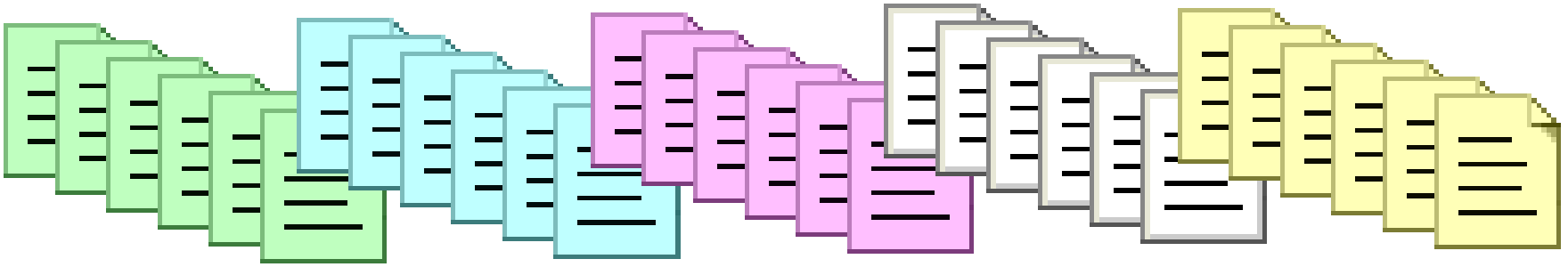
- The number of possible states must be finite (no open-ended counters, no random)
- Combinatorial explosion (6 bools = pages x 64)



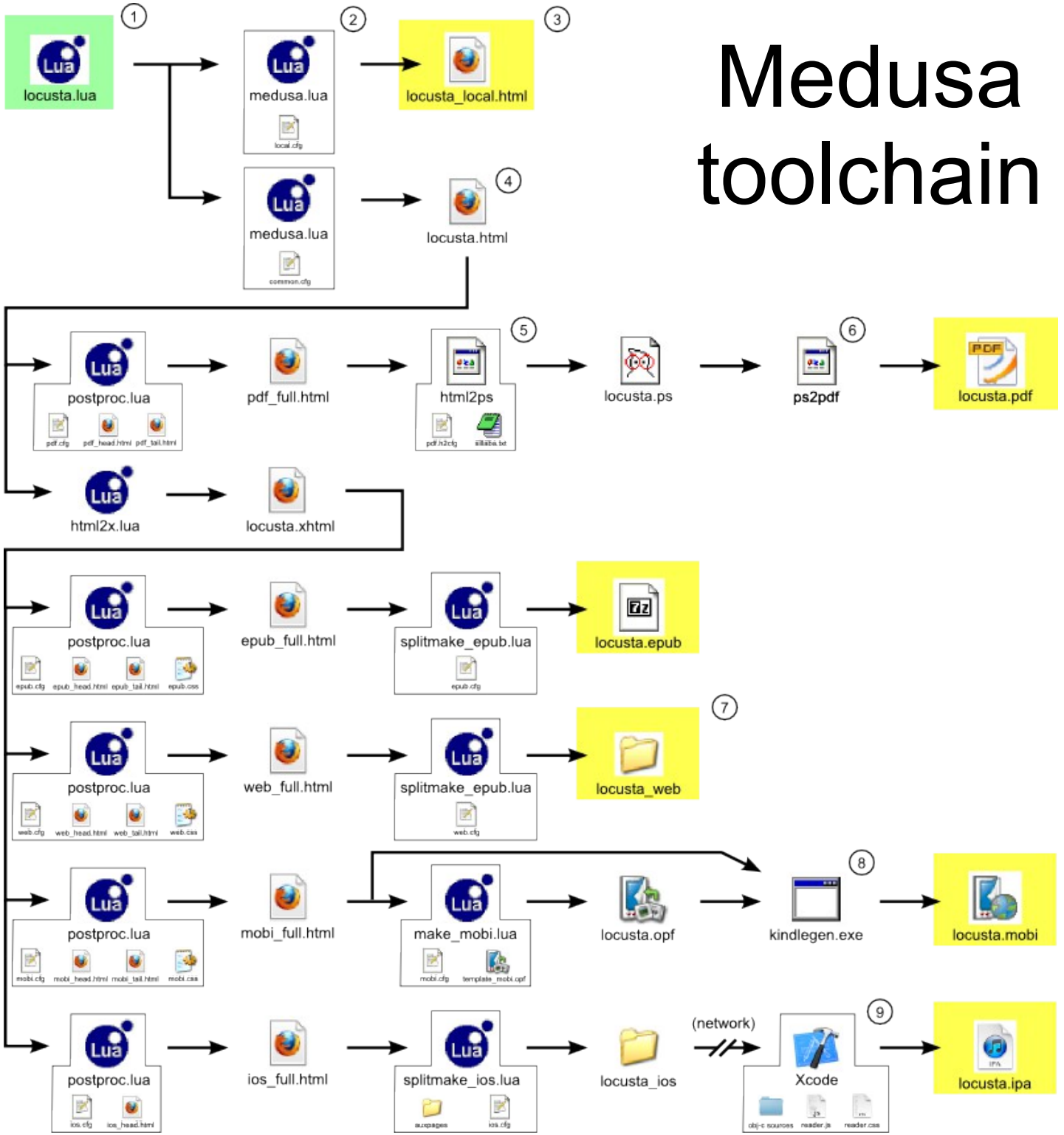
Page budget



- Printed book: 100s of pages (cost)
- Ebook: 1,000s of pages (e-reader limitations)
- Static website: 1,000,000s of pages (space, fs)
- Combinatorial explosion must be limited
- Localize states, use patterns
- Hard to do by hand



Medusa toolchain

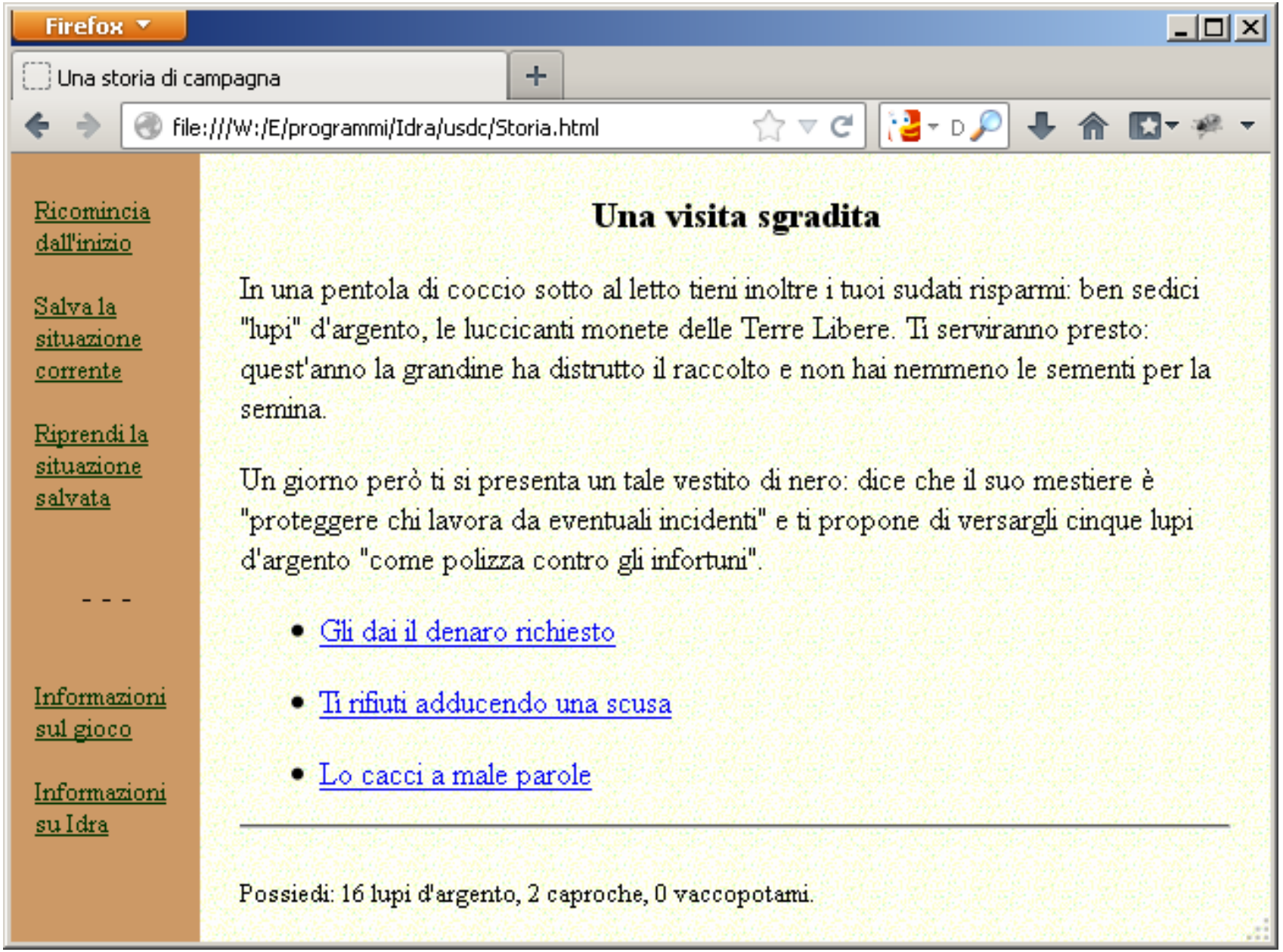


With a little help from Lua...

- An adventure game ebook
- Puzzles of different types
- Items to pick up, dialogs
- Free exploration
- Multiple characters
- Counters, timers
- 940 (small) source pages
- 5800 instance (‘printed’) pages, 11000 links

(in Italian only)

An old JS framework: Idra



Idra ‘book’ structure

```
function Kitchen() {
  title("The room is on fire")
  text("Things are getting rather hot here.")
  choice("Get out immediately", Garden)
  choice("Grab the beer can and get out",
         "v.beer = 1; go(Garden)")
}
```

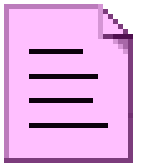
- Each page is a function
- Page content is ‘printed’ by API calls
- Link actions may contain code
- The state is changed by the link action

Variable page content

```
function Garden() {
   title("Garden outside burning house")
   if (v.beer == 1) {
      text("You are holding a beer can.")
   }
   // ...
}
```

- The **v.** object (table) contains the state
- The same page function (source page) may ‘print’ different content (instance pages)
- Usual game logic programming

Back to the ebook

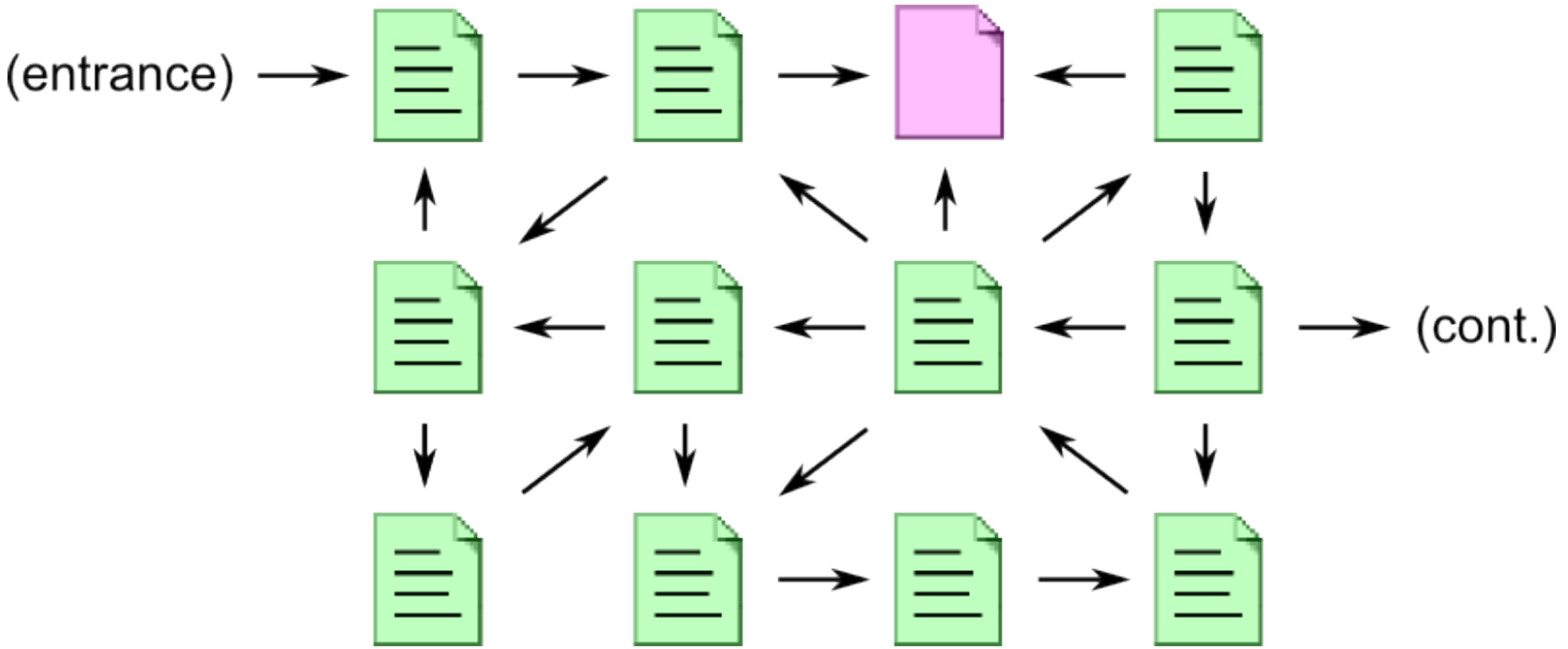


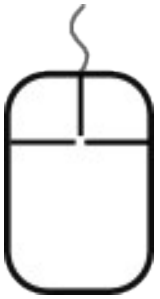
- Could we reuse the same approach?

- Pages are immutable, there is no runtime
- How to keep track of the state?
- How to change the state on link action?
- How to print different content depending on state?
- How to allow a ‘normal’ programming style?

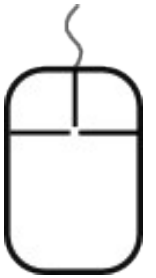
Ebook as directed graph

- Nodes are pages
- No predictable structure, cycles are common





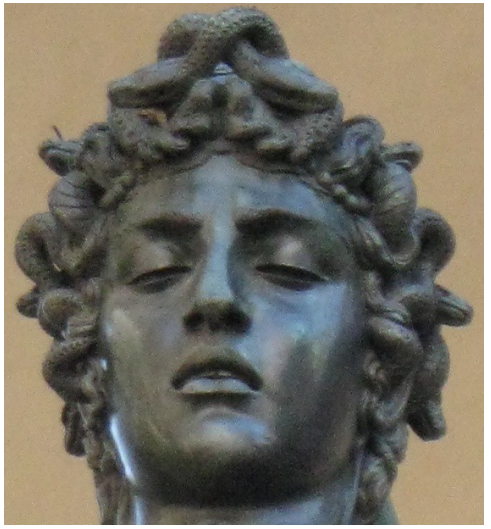
Just click on all links



- The number of nodes (instance pages) is finite
- We can enumerate them:

- Start with an Idra-like source, at the first page
- ‘Print’ the page with the initial state
- Simulate clicking on a link, execute its code
- ‘Print’ the destination page with changed state
- Repeat recursively, recognizing visited nodes

The Medusa compiler



- Caveat: unrefined tool, made for my own use
- No error handling, no documentation
- HTML generation is very primitive
- ...but it worked fine for my project

Book source format

```
# landing

if not v.count then v.count = 9 end

if v.count > 0 then
    P(v.count, " seconds to touchdown.")
    Choice("Wait", 'landing',
           F{v.count = v.count - 1} )
else
    P"We have landed on the Moon!"
end
```

- A source page is Lua code
- A link can contain Lua code

Macro replacement

```
function page.landing(_ENV)

if not v.count then v.count = 9 end

if v.count > 0 then
    P(v.count, " seconds to touchdown.")
    Choice("Wait", 'landing',
     function(_ENV) v.count = v.count - 1 end)
else
    P"We have landed on the Moon!"
end

end
```

- Page and links become Lua functions

The vtable

- A vtable represents the current state
- “Variables table” (nothing to do with C++)

```
v = { count=7 }
```

- Vtables are shallow but can contain any number or type of scalar values

```
v = { ship='Niña', days=35, landInView=false }
```

- Two instance pages of the same source page with equal vtables are the same instance page

Page generation

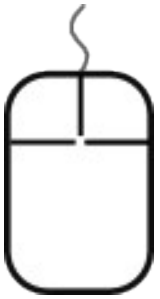
- Source page + vtable = Instance page

```
function page.landing(_ENV)
    ...
    P(v.count, " seconds to touchdown.")
    ...
end
```

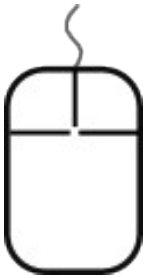
- The source page function is called with the current vtable in its environment

```
v = { count=7 }
```

```
Output: <p>7 seconds to touchdown.</p>
```



Link generation



- The link function is called with a copy of the current vtable in its environment
- The link function can change the vtable content

```
Choice("Wait", 'landing',
     function(_ENV) v.count = v.count - 1 end )
```

- If the resulting instance page (source + vtable) exists, its name is put into the link
- If not, a new instance page name is generated and a (source + vtable) request is queued

Link output

```
v = { count=7 } -- copy of source page vtable
```

```
Choice("Wait", 'landing',
     function(_ENV) v.count = v.count - 1 end )
```

```
v = { count=6 } -- after link function call
```

- An instance page is requested with:
  `source_page='landing', v = { count=6 }`
- It does not exist, so a new name is generated for the (queued) instance page:

```
Output: <a href="#landing__4">Wait</a>
```

Queue serving

- When the page is complete, queued instance pages are generated the same way

```
<a name="landing__4"><!-- --></a>
<p>6 seconds to touchdown.</p>
<ul><li><a
href="#landing__5">Wait</a></li></ul>
```

- They may queue requests for other pages:

```
<a name="landing__5"><!-- --></a>
<p>5 seconds to touchdown.</p>
<ul><li><a
href="#landing__6">Wait</a></li></ul>
```

Reporting

```
-------------------------------
-- Created pages by page name:

landing
    landing__1   {}
    landing__2   { count=8, }
    landing__3   { count=7, }
    landing__4   { count=6, }
    landing__5   { count=5, }
    landing__6   { count=4, }
    landing__7   { count=3, }
    landing__8   { count=2, }
    landing__9   { count=1, }
    landing__10   { count=0, }
```

4 levels of Lua

- The Medusa compiler
- The source pages
- The link functions
- The configuration file

- The levels run in different environments
- Source code is executed during compilation rather than at runtime (metaprogramming, sort of)

Wolf, goat and cabbage

This is the river bank nearest to home; I have to bring all three items undamaged to the other bank.

Here is the wolf I have to ferry across the river.
Here is the goat I have to ferry across the river.
Here is the cabbage I have to ferry across the river.

- Take the wolf
- Take the goat
- Take the cabbage
- Cross the river alone

Instance pages created

- Unreachable pages are not created
- No need for pruning

```
------------------------
-- Pages by name:

    5  farside
    1  lost
    5  nearside
   20  river
    1  start
    1  won
```

Page vtables (report)

```
river
    river__1   { cabbage=1, goat=1, wolf=3, }
    river__2   { cabbage=1, goat=3, wolf=1, }
    river__3   { cabbage=3, goat=1, wolf=1, }
    river__4   { cabbage=1, goat=1, wolf=1, }
    river__5   { cabbage=1, goat=2, wolf=1, }
    river__6   { cabbage=1, goat=2, wolf=3, }
    river__7   { cabbage=3, goat=2, wolf=1, }
    river__8   { cabbage=2, goat=3, wolf=1, }
    river__9   { cabbage=2, goat=2, wolf=1, }
    river__10   { cabbage=2, goat=1, wolf=3, }
    river__11   { cabbage=2, goat=1, wolf=1, }
    river__12   { cabbage=3, goat=1, wolf=2, }
    river__13   { cabbage=2, goat=1, wolf=2, }
    river__14   { cabbage=2, goat=3, wolf=2, }
    river__15   { cabbage=2, goat=2, wolf=3, }
    river__16   { cabbage=3, goat=2, wolf=2, }
    river__17   { cabbage=2, goat=2, wolf=2, }
    river__18   { cabbage=1, goat=3, wolf=2, }
    river__19   { cabbage=1, goat=1, wolf=2, }
    river__20   { cabbage=1, goat=2, wolf=2, }
```

Debugging

[farside__1, { cabbage=1, goat=2, wolf=1, }]

On the river

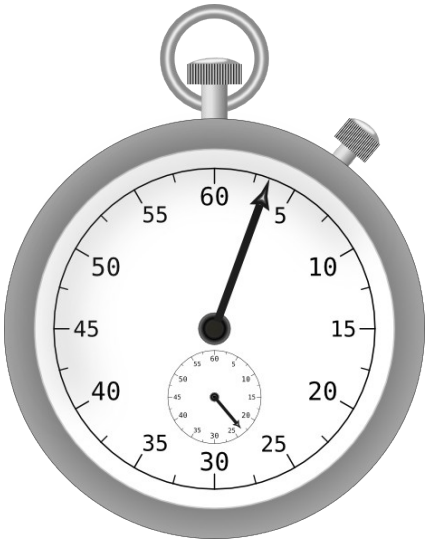
This is the river bank nearest to the market.

I brought the goat here.

- Ferry back the goat [river__2, { cabbage=1, goat=3, wolf=1, }]
- Cross the river alone [river__5, { cabbage=1, goat=2, wolf=1, }]

Performance

- Times on an old Pentium 4, including reporting:
- My game-ebook (943 / 5817 pages): 1.64 s
- 1 / 1000 pages: 0.11 s
- 1 / 10k pages: 0.94 s
- 1 / 100k pages: 9.64 s
- 1 / 1M pages: 96.8 s



- Almost O(n), no worst case
- Reading / post-processing takes much longer

Use of environments

- Lua 5.1: setfenv()
- Lua 5.2: _ENV and textual substitution (works, but not a perfect solution)
- Could be done with a proxy environment, just switching the vtable, or with an upvalue
- Should preserve cross-page insulation
- Should also allow common sub-functions
- Should control access to vtable, functions, etc.
- Many ways to solve problems in Lua!

Possible improvements

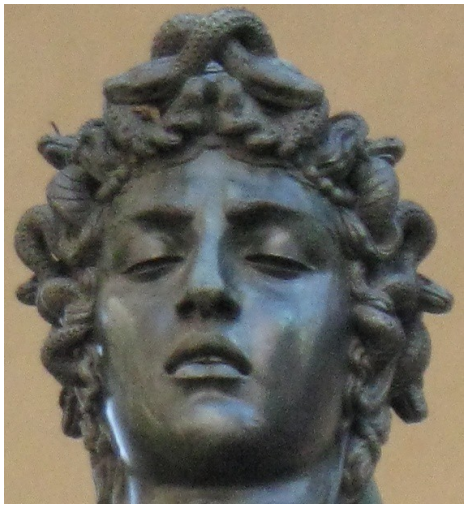
- Common functions callable from pages
- Automated timers
- Subpages with return stack
- Random choices (simulation)

- Better HTML (esp. classes)
- Make it production-ready (error handling etc.)
- Add user-friendly GUI editor

That's all, folks

Medusa compiler and samples at:

http://www.erix.it/medusa.html



Some images are taken from "Interactive fiction & ebooks" (Enrico Colombini, quintadicopertina)