

## Dednat6: An extensible (semi-)preprocessor for Lua<sup>A</sup>T<sub>E</sub>X that understands diagrams in ASCII art

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### 1 Prehistory

Many, many years ago, when I was writing my master’s thesis, I realized that I was typesetting too many natural deduction trees, and that this was driving me mad. The code (in `proof.sty`) for a small tree like this one

$$\frac{\frac{[a]^1 \quad a \rightarrow b}{b} \quad b \rightarrow c}{\frac{c}{a \rightarrow c} \quad 1}$$

was this:

```
\infer[{}]{ a\to c }{
  \infer[{}]{ c }{
    \infer[{}]{ b }{
      [a]^1 &
      a\to b } &
      b\to c } } }
```

This was somewhat manageable, but the code for bigger trees was very hard to understand and to debug. I started to add 2D representations of the typeset trees above the code, and I defined a macro `\defded` to let me define the code for several trees at once, and a macro `\ded` to invoke that code later:

```
% [a]^1 a->b
% -----
%      b      b->c
%      -----
%      c
%      ----1
%      a->c
%
%      ^a->c
%
\defded{a->c}{
  \infer[{}]{ a\to c }{
    \infer[{}]{ c }{
      \infer[{}]{ b }{
        [a]^1 &
        a\to b } &
        b\to c } } }
%
$$\ded{a->c}$$
```

Then I realized that if I made the syntax of my 2D representations a bit more rigid, I could write a preprocessor that would understand them directly, and write all the `\defded`’s itself to an auxiliary file. If a file `foo.tex` had this (note: I will omit all

header and footer code, like `\begin{document}` and `\end{document}`, from the examples),

```
\input foo.dnt
```

```

%: [a]^1 a->b
%: -----
%:      b      b->c
%:      -----
%:      c
%:      ----1
%:      a->c
%:
%:      ^a->c
```

```
$$\ded{a->c}$$
```

then I just had to run “`dednat.icn foo.tex;latex foo.tex`” instead of “`latex foo.tex`”.

### 2 dednat.lua

A few years after that, I learned Lua, fell in love with it, and ported `dednat.icn` from Icon — which was a *compiled* language — to Lua.

The first novel feature in `dednat.lua` was a way to run arbitrary Lua code from the `.tex` file being preprocessed, and so extend the preprocessor dynamically. `dednat.lua` treated blocks of lines starting with ‘%:’ as specifications of trees, and blocks of lines starting with ‘%L’ as Lua code. More precisely, the initial set of *heads* was {“%:”, “%L”, “%D”}, and `dednat.lua` processed each block of contiguous lines starting with the same head in a way that depended on the head.

The second novel feature in `dednat.lua` was a way to generate code for categorical diagrams, or “2D diagrams” for short, automatically, analogous to what we did for trees. I wanted to make the preprocessor write the `\defdiag`’s seen here itself:

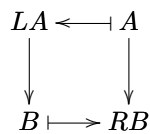
```
% LA <-| A
% |      |
% v      v
% B |-> RB
%
\defdiag{adj_L-|R}{
  \morphism(0,0)/<-|/<400,0>[LA`A;]
  \morphism(0,0)/->/<0,-400>[LA`B;]
  \morphism(400,0)/->/<0,-400>[A`RB;]
  \morphism(0,-400)/|->/<400,0>[B`RB;]
}
$$\diag{adj_L-|R}$$
```

where `\morphism` is the main macro in `diagxy`, Michael Barr’s front-end for `XY-pic`.

After months of experimentation I arrived at a good syntax for 2D diagrams. This code:

```
%D diagram adj_L-|R
%D 2Dx      100    +25
%D 2D      100 LA <-| A
%D 2D        |      |
%D 2D        |      |
%D 2D        v      v
%D 2D    +25 B |-> RB
%D 2D
%D (( LA A <-|
%D      LA B -> A RB ->
%D      B RB |->
%D ))
%D enddiagram
%D
$$$diag{adj_L-|R}$$$
```

generates this:



The lines with ‘%D 2Dx’ and ‘%D 2D’ define a grid with coordinates and nodes, and the lines between ‘%D ((’ and ‘%D ))’ connect these nodes with arrows.

### 2.1 A Forth-based language for 2D diagrams — low-level ideas

The article “Bootstrapping a Forth in 40 lines of Lua code” [1] describes how a Forth-like language can be reduced to a minimal extensible core, and bootstrapped from it. The most basic feature in [1] is “words that eat text”; the fact that Forth is a stack-based language is secondary — stacks are added later. The code for ‘%D’-lines is based on [1].

A “Forth” — actually the “outer interpreter” of a Forth, but let’s call it simply a “Forth” — works on one line of input at a time, reads each “word” in it and executes it as soon as it is read. A “word” is any sequence of one or more non-whitespace characters, and an input line is made of words separated by whitespace. The “outer interpreter” of Forth does essentially this on each line, in pseudocode:

```
while true do
  word = getword()
  if not word then break end
  execute(word)
end
```

Note that `word` is a global variable. The current input line is stored in `subj` and the current position of the parser is stored in `pos`; `subj` and `pos` are also global variables — which means the `execute(word)` can change them!

The function `getword()` parses whitespace in `subj` starting at `pos`, then parses a word and returns

it, and advances `pos` to the position after that word. There is a similar function called `getrestofline()` that returns all the rest of the line from `pos` onwards, and advances `pos` to the end of the line.

One of the simplest Forth words is ‘#’ (“comment”). It is defined as:

```
forths["#"] = function ()
  getrestofline()
end
```

It simply runs `getrestofline()`, discards its return value, and returns. We say that # “eats the rest of the line”.

In a “real” Forth we can define words using ‘:’ and ‘;’, like this:

```
: SQUARE DUP * ;
```

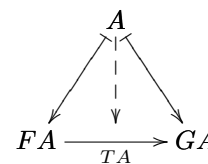
but the Forth-based language in `dednat.lua` is so minimalistic that we don’t have ‘:’ and ‘;’ — we define words by storing their Lua code in the table `forths`.

### 2.2 A Forth-based language for 2D diagrams — code for diagrams

Let’s look at an example. This code

```
%D diagram T:F->G
%D 2Dx      100 +20 +20
%D 2D      100      A
%D 2D        /|\
%D 2D        v v v
%D 2D    +30 FA --> GA
%D 2D
%D (( A FA |-> A GA |->
%D      FA GA -> .plabel= b TA
%D      A FA GA midpoint -->
%D ))
%D enddiagram
%D
$$$diag{T:F->G}$$$
```

yields this:



The word `diagram` eats a word — the name of the diagram — and sets `diagramname` to it. The word `2Dx` eats the rest of the line, and uses it to attribute *x*-coordinates to some columns. The word `2D` also eats the rest of the line; when it is followed by *nnn* or *+nnn* that number gives the *y*-coordinate of that line, and the words that intersect a point that has both an *x*-coordinate and a *y*-coordinate become *nodes*. When a `2D` is not followed by an *nnn*

or  $+nnn$  then this is a line without a  $y$ -coordinate, and it is ignored.

In a sequence like “A FA  $|->$ ”, both A and FA put nodes on the stack, and  $|->$  creates an arrow joining the two nodes on the top of the stack, without dropping the nodes from the stack. In a sequence like “FA GA midpoint” the `midpoint` creates a phantom node halfway between the two nodes on the top of the stack, drops (pops) them and pushes the phantom node in their place. The word `.plabel=` eats two words, a *placement* and a *label*, and modifies the arrow at the top of the stack by setting the arrow’s label and placement attributes with them. The word `((` remembers the depth of the stack — 42, say — and the word `)` pops elements from the top of the stack; if the depth at `)` is 200 then `)` pops 200 — 42 elements to make the depth become 42 again.

The word `enddiagram` defines a diagram with the name stored in `diagramname`; each arrow that was created, even the ones that were dropped from the stack, becomes a call to `\morphism` — the main macro in `diagxy` — in the body of the diagram.

A good way to understand in detail how everything works is to inspect the data structures. Let’s modify the code of the example to add some `print`’s in `%L`-lines in the middle of the `%D`-code:

```
%D diagram T:F->G
%D 2Dx      100 +20 +20
%L print("xs:"); print(xs)
%D 2D      100      A
%D 2D      /|\
%D 2D      v v v
%D 2D +30 FA --> GA
%L print("nodes:"); print(nodes)
%D 2D
%D (( A FA |-> A GA |->
%D   FA GA -> .plabel= b TA
%D   A FA GA midpoint -->
%L print("ds:"); print(ds)
%D ))
%L print("arrows:"); print(arrows)
%D enddiagram
```

The preprocessor outputs this on stdout:

```
xs:
{12=100, 16=120, 20=140}
nodes:
{ 1={"noden"=1, "tag"="A", "x"=120, "y"=100},
  2={"noden"=2, "tag"="FA", "x"=100, "y"=130},
  3={"noden"=3, "tag"="-->", "x"=120, "y"=130},
  4={"noden"=4, "tag"="GA", "x"=140, "y"=130},
  "-->={"noden"=3, "tag"="-->", "x"=120, "y"=130},
  "A"={"noden"=1, "tag"="A", "x"=120, "y"=100},
  "FA"={"noden"=2, "tag"="FA", "x"=100, "y"=130},
  "GA"={"noden"=4, "tag"="GA", "x"=140, "y"=130}
}
```

```
ds:
12={"arrown"=4, "from"=1, "shape"="-->", "to"=5}
11={"TeX"="\phantom{0}", "noden"=5, "x"=120,
    "y"=130}
10={"noden"=1, "tag"="A", "x"=120, "y"=100}
9={"arrown"=3, "from"=2, "label"="TA",
   "placement"="b", "shape"="-->", "to"=4}
8={"noden"=4, "tag"="GA", "x"=140, "y"=130}
7={"noden"=2, "tag"="FA", "x"=100, "y"=130}
6={"arrown"=2, "from"=1, "shape"="|->", "to"=4}
5={"noden"=4, "tag"="GA", "x"=140, "y"=130}
4={"noden"=1, "tag"="A", "x"=120, "y"=100}
3={"arrown"=1, "from"=1, "shape"="|->", "to"=2}
2={"noden"=2, "tag"="FA", "x"=100, "y"=130}
1={"noden"=1, "tag"="A", "x"=120, "y"=100}
arrows:
{ 1={"arrown"=1, "from"=1, "shape"="|->", "to"=2},
  2={"arrown"=2, "from"=1, "shape"="|->", "to"=4},
  3={"arrown"=3, "from"=2, "label"="TA",
    "placement"="b", "shape"="-->", "to"=4},
  4={"arrown"=4, "from"=1, "shape"="-->", "to"=5}
}
```

### 3 Semi- preprocessors

`dednat.icn`, `dednat.lua` and all its successors until `dednat5.lua` were preprocessors in the usual sense — they had to be run *outside latex* and *before latex*. With `dednat6` this changed; `dednat6` can still be run as a preprocessor, but the recommended way to run it on, say, `foo.tex`, is to put a line like

```
\directlua{dofile "dednat6load.lua"}
```

somewhere near the beginning of `foo.tex`, add some calls to `\pu` at some points — as we will explain soon — and compile `foo.tex` with `lualatex` instead of `latex`, to make `foo.tex` be processed “in parallel” by `TeX` and by Lua. That “in parallel” is a simplification, though; consider this example:

```

%:
%:  a  b
%:  ----
%:  c
%:
%:  ~my-tree
%:
%:  $$\pu\ded{my-tree}$$
%:
%:  d  e  f
%:  -----
%:  g
%:
%:  ~my-tree
%:
%:  $$\pu\ded{my-tree}$$
```

Suppose that this fragment starts at line 20. (As mentioned above, we are omitting the header and footer — e.g., `\begin{document}` and `\directlua{dofile "dednat6load.lua"}`.)

We have a `%:-`-block from lines 20–26, a call to `\pu` at line 27, another `%:-`-block from lines 28–34, and another call to `\pu` at line 35.

The output of the first `%:-`-block above is a `\defded{my-tree}`, and the output of the second `%:-`-block above is a *different* `\defded{my-tree}`.

`\pu` means “process until” — or, more precisely, *make dednat6 process everything until this point that it hasn’t processed yet*. The first `\pu` processes the lines 1–26 of `foo.tex`, and “outputs” — i.e., sends to `TEX` — the first `\defded{my-tree}`; the second `\pu` processes the lines 28–34 of `foo.tex`, and “outputs” the second `\defded{my-tree}`. Thus, it is not technically true that `TEX` and `dednat6` process `foo.tex` in parallel; `dednat6` goes later, and each `\pu` is a synchronization point.

### 3.1 Heads and blocks

In order to understand how this idea — “semi-preprocessors” — is implemented in `dednat6` we need some terminology.

The initial set of heads is `{ "%:", "%L", "%D" }`. It may be extended with other heads, but we may only add heads that start with `%`.

A block is a set of contiguous lines in the current `.tex` file. This code

```
Block {i=42, j=99}
```

creates and returns a block that starts on line 42 and ends on line 99. The Lua function `Block` receives a table, changes its metatable to make it a “block object”, and returns the modified table.

A head block is a (maximal) set of contiguous lines all with same head. Head blocks are implemented as blocks with an extra field `head`. For example:

```
Block {i=20, j=26, head="%:"}
```

A block is *bad* when it contains a part of a head block but not the whole of it. We avoid dealing with bad blocks — `dednat6` never creates a block object that is “bad”.

Each head has a *processor*. *Executing* a head block means running it through the processor associated with its head. Executing an arbitrary (non-bad) block means executing each head block in it, one at a time, in order. Note: the code for executing non-bad arbitrary blocks was a bit tricky to implement, as executing a `%L`-block may change the set of heads and the processors associated to heads.

A *texfile block* is a block that refers to the whole of the current `.tex` file, and that has an extra field `nline` that points to the first line that `dednat6` hasn’t processed yet. If `foo.tex` has 234 lines then the `texfile` block for `foo.tex` starts as:

```
Block {i=1, j=234, nline=1}
```

We saw in sections 1 and 2.2 that the “output” of a `%:-`-block is a series of `\defded`’s and the “output” of a `%D`-block is a series of `\defdiags`’s. We can generalize this. For example, the “output” of

```
%L output [[\def\Foo{F00}]]
```

```
%L output [[\def\Bar{BAR}]]
```

is

```
\def\Foo{F00}
```

```
\def\Bar{BAR}
```

The *output* of a head block is the concatenation of the strings sent to `output()` when that block is executed. The output of an arbitrary (non-bad) block is the concatenation of the strings sent to `output()` by its head blocks when the arbitrary block is executed.

A `\pu`-block is created by `dednat6` when a `\pu` is executed, pointing to the lines between this `\pu` and the previous `\pu`. If `foo.tex` has a `\pu` at line 27 and another at line 35 then the first `\pu` creates this block,

```
Block {i=1, j=26}
```

and the second `\pu` creates this:

```
Block {i=28, j=34}
```

As `\pu`’s only happen in non-comment lines, `\pu`-blocks are never bad.

### 3.2 The implementation of `\pu`

The macro `\pu` is defined as

```
\def\pu{\directlua{
  processuntil(tex.inputlineno)
}}
```

in `LATEX`, and `processuntil()` is this (in Lua):

```
processuntil = function (puline)
  local publock =
    Block {i=tf.nline, j=puline-1}
  publock:process()
  tf.nline = puline + 1
end
```

Here’s a high-level explanation. When `dednat6` is loaded and initialized it creates a `texfile` block for the current `.tex` file — with `nline=1` — and stores it in the global variable `tf`. The macro `\pu` creates a `\pu`-block that starts at line `tf.nline` and ends at line `tex.inputlineno - 1`, executes it, and advances `tf.nline` — i.e., sets it to `tex.inputlineno + 1`.

The code above looks simple because the line `publock:process()` does all the hard work.

## 4 Creating new heads

New heads can be created with `registerhead`, and they are recognized immediately. For example, this

```
%L eval = function (str)
%L   return assert(loadstring(str))()
%L end
%L expr = function (str)
%L   return eval("return "..str)
%L end
%L
%L registerhead "%A" {
%L   name   = "eval-angle-brackets",
%L   action = function ()
%L     local i,j,str = tf:getblockstr()
%L     str = str:gsub("<(-)>", expr)
%L     output(str)
%L   end,
%L }
%A $2+3 = <2+3>$
\pu
```

produces “ $2 + 3 = 5$ ”; that looks trivial, but it is easy to write bigger examples of ‘`%A`’-blocks with `pict2e` code in them, in which the Lua expressions in ‘`<...>`’s generate ‘`\polyline`’s and ‘`\puts`’s whose coordinates are all calculated by Lua.

## 5 A read-eval-print-loop (REPL)

Dednat6 uses only one function from the Lua<sub>TEX</sub> libraries—`tex.print`—and two variables, `status.filename` and `tex.inputlineno`, but it includes a nice way to play with the other functions and variables in the libraries.

Dednat6 includes a copy of `lua-repl` (by Rob Hoelz, [github.com/hoelzro/lua-repl](https://github.com/hoelzro/lua-repl)), and we can invoke it by running `luarepl()`. If we put this in our `foo.tex`,

```
\setbox0=\hbox{abc}
\directlua{luarepl()}
```

then running `lualatex foo.tex` will print lots of stuff, and then the prompt ‘`>>>`’ of the `lua-repl` inside `dednat6`; if we send these commands to the REPL,

```
print(tex.box[0])
print(tex.box[0].id,      node.id("hlist"))
print(tex.box[0].list)
print(tex.box[0].list.id, node.id("glyph"))
print(tex.box[0].list.char, string.byte("a"))
print(tex.box[0].list.next)
print(tex.box[0].list.next.char,
      string.byte("b"))
```

we get this in the terminal:

```
>>> print(tex.box[0])
<node nil < 35981 > nil : hlist 2>
>>> print(tex.box[0].id,      node.id("hlist"))
0 0
>>> print(tex.box[0].list)
<node nil < 6107 > 6114 : glyph 256>
>>> print(tex.box[0].list.id, node.id("glyph"))
29 29
>>> print(tex.box[0].list.char, string.byte("a"))
97 97
>>> print(tex.box[0].list.next)
<node 6107 < 6114 > 32849 : glyph 256>
>>> print(tex.box[0].list.next.char,
>>>> string.byte("b"))
98 98
>>>
```

The best way to use `luarepl()`—in my not so humble opinion—is from Emacs, with the `eev` library. The tutorial of `eev` at

[http://angg.twu.net/eev-intros/  
find-eev-quick-intro.html](http://angg.twu.net/eev-intros/find-eev-quick-intro.html)

explains, in the section “Controlling shell-like programs”, how we can edit the commands to be sent to `lualatex` in a buffer, called the “notes buffer”, and send them line by line to another buffer that runs `lualatex foo.tex` in a shell—the “target buffer”; each time that we type the F8 key Emacs sends the current line to the program running in the target buffer, *as if the user had typed it*.

## 6 Availability

Dednat6 is not in CTAN yet (as of October, 2018). Until it gets there you can download it from:

<http://angg.twu.net/dednat6.html>

## References

[1] E. Ochs: *Bootstrapping a Forth in 40 Lines of Lua Code*. Chapter 6 (pp. 57–70) of *Lua Programming Gems*, L.H. de Figueiredo, W. Celes, and R. Ierusalimschy, eds. [lua.org/gems](http://lua.org/gems), 2008. Available from <http://angg.twu.net/miniforth-article.html>.

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