# The words in a MITC Forth

Alvaro G. S. Barcellos,
agsb at github,
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## the inner interpreter

*“: NEXT IP )+ W MOV W )+ ) JMP ;*

*Now Forth was complete. And I knew it.”*

*Charles H. Moore,*

*“Forth - The Early Years”, PDP-11*

The inner interpreter is Forth's *heartbeat*.

The dictionary is the Forth’s *DNA*.

# the Minimal Indirect Thread Code

1. *Any primitive word contains only a machine code*
2. *All primitive words are performed in a similar way to ‘link and jump’*
3. *Any compound word contains only a list of word references*
4. *All compound words have the references 'pushed and pulled' onto the return stack*
5. *Any compound word should only access the return stack using >R R> R@*

## Notes

*The ‘jump and link’ concept was used by Charles H. Moore in 70’s when --IP holds the address to next instruction--.*

*In the follow examples:*

*The names NEXT, NEST (aka doCOL), UNNEST (aka SEMIS), are classic names for Forth inner interpreter, LINK and JUMP are traditional.*

*Using reference ITC from FIG-Forth for PDP-11*

*Using PDP-11, Instruction Set Architecture (ISA)*

*By convention, stacks grows downward, (X) indirect access, increment+ (pós), -decrement (pré)*

# the MITC dictionary

```
compound:    a list of references, ends with ENDS

+-------+--------+-------+--------+-------+
| HERE  | STORE  | CELL  | ALLOT  | ENDS  |
+CFA----+--------+-------+--------+-------+

primitive:   starts with NULL and ends with a jump

+-------+-------+-------+-------+-------+-------+
| NULL  | code  | code  | code  | code  | LINK  |
+CFA----+-------+-------+-------+-------+-------+

PS. "headers" not showed,
NULL is 0x0000, LINK is 'jump link'
```

## call or link

```
from PDP-11 ISA

          JSR Ri, Src  // Jump into subroutine
          -(SP) ← Ri; Ri ← +PC; PC ← Src;
          RTS          // Return from subroutine
              PC ← Ri; Ri ← (SP)+;

push and pull    // same, but do not use Ri
          CALL Src
              -(SP) ← Ri; Ri ← +PC; PC ← Src;
          RETURN
              PC ← Ri; Ri ← (SP)+;

link and jump    // same, but do not use SP
          JAL Ri, Src
              -(SP) ← Ri; Ri ← +PC; PC ← Src;
          JR Ri
              PC ← Ri; Ri ← (SP)+;
```

# the code of MITC

```
unest:  MOV (RP)+, IP      // .pull
next:   MOV (IP)+, W       // .cast
        TST W
        BEQ jump
nest:   MOV IP, -(RP)      // .push
link:   MOV W, IP          // .link
        JMP next
jump:   MOV (RP)+, W       // .jump
        JMP (IP)
```

```
from FIG-Forth, 1.3.3.1:

SEMIS : MOV (RP)+, IP
        NEXT

NEXT  : MOV (IP)+, W
        JMP @(W)+

DOCOL : MOV IP, -(RP)
        MOV W, IP
        NEXT
```

```
HEADER “ENDS”,’ends’
.word    0x000
unnest: …
```

## the code of MITC

```
unnest:  MOV (RP)+, IP     // .pull
next:    MOV (IP)+, W      // .cast
         TST W
         BEQ jump
nest:    MOV IP, -(RP)     // .push
link:    MOV W, IP         // .link
         JMP next
jump:    MOV (RP)+, W      // .jump
         JMP (IP)
```

*reference version,*
marked is same code as in
FIG-Forth PDP-11 1.3.3.1

W is the next caller
IP is the last callee

```
HEADER "ENDS",'ends'
.word    0x000
unnest: …
```

## ITC and MITC

In ITC

1. uses two registers, both are scratch
2. CFA is always a reference to a machine code routine
3. must jump twice for every word

In MITC

1. uses two registers, one must be preserved (link register)
2. CFA is always a reference to a word or a NULL
3. must test the CFA of each word but only jump when it is NULL
4. *performs a deep-first search for primitive words*

MITC

## inside words

## FIG-Forth ITC, inside words

```
doVAR: MOV W, -(SP) ; NEXT ;

doCON: MOV (W), –(SP) ; NEXT ;

LIT:   MOV (IP)+, -(SP) ; NEXT ;

BRANCH: ADD (IP), IP ; NEXT ;

EXEC: MOV (SP)+, W ; JMP @(W)+ ;

(VALUE): MOV (SP)+, (IP)+ ; NEXT ;
```

# MITC, inside words

```
doVAR: MOV W+, −(SP) ; LINK ;

doCON: MOV (W)+, −(SP) ; LINK ;

LIT:   MOV (W)+, -(SP) ; LINK ;

BRANCH: ADD (W), W ; LINK ;

EXEC: MOV W, -(RP) ; MOV (SP)+, W ; LINK ;

(VALUE): MOV (SP)+, (W)+ ; LINK ;
```

## MITC, PDP-11

```
unnest:  MOV (RP)+, WP     // .pull
next:    MOV (WP)+, IP     // .cast
         TST IP
         BEQ jump
nest:    MOV WP, -(RP)     // .push
link:    MOV IP, WP        // .link
         JMP next
jump:    MOV (RP)+, IP     // .jump
         JMP (WP)
```

pull, push, move, cast, jump

`syntax from, to`

wp, work pointer, scratch
ip, link pointer, reserved
rp, return stack pointer, reserved

(use of IP and WP has been swapped)

```
// ends is unnest
HEADER"ENDS",ends,
.word   0x000
unnest:
```

# MITC as macros

```
HEADER,'ENDS', ends,
.word    0x0000
unnest:  PULL wp, rp
next:    PULL ip, wp
         TST ip
         BEQ jump
nest:    PUSH wp, rp
link:    MOVE wp, ip
         JUMP next
jump:    PULL ip, rp
         JUMP (wp)
```

*syntax to, from*

wp, work pointer, scratch
ip,  link pointer, reserved
rp, return stack pointer, reserved

#cell is the cell size of Forth

do not use any default link register

primitive code starts with 0x0000
primitive code ends with JUMP link:

PULL also increments pointer,
PUSH also decrements pointer

## Notes

```
words to tweak
    DOES> DEFER IS
    VALUE TO
    RECURSE EXIT
    ALIAS ASSIGN
    :NONAME ;CODE
```

## Easy summary

```
In ITC, the inner interpreter

    Always jumps to address at first cell of word definition
    (DOCOD, DOCOL, DOVAR, DOCON, DODOE, etc)

In MITC, the inner interpreter

    Only jumps when is a primitive.
    (DOCOD)
```

## conclusion

**When reinvent the wheel ?**

*MITC is a faster inner interpreter;*

*MITC is more effective than ITC;*

*MITC needs little changes at few primitive words;*

*MITC uses less memory and less jumps;*

## references

https://library.nrao.edu/public/memos/comp/CDIR_17.pdf

https://pdos.csail.mit.edu/6.828/2005/readings/pdp11-40.pdf

http://www.stackosaurus.com/figforth-1.3.3.1/FORTH.MAC

http://www.complang.tuwien.ac.at/forth/threaded-code.html

http://www.bradrodriguez.com/papers/moving1.htm

https://muforth.nimblemachines.com/threaded-code/

http://git.annexia.org/?p=jonesforth.git;a=tree

https://home.hccnet.nl/a.w.m.van.der.horst/lina.html

https://github.com/simh/simh

# MITC, Risc-V

```
unnest:  lw W, 0(RP)
         addi RP, RP, 1 * #CELL
next:    lw IP, 0(W)
         addi W, W, 1 * #CELL
         BEQ IP, zero, jump
nest:    addi RP, RP, -1 * CELL
         sw 0(RP), W
link:    add W, IP, zero
         jal zero, next
jump:    lw IP, 0(RP)
         addi RP, RP, 1 * #CELL
         jalr zero, 0(W)
```

pull, push, link, cast, jump

syntax to, from

not use default link register

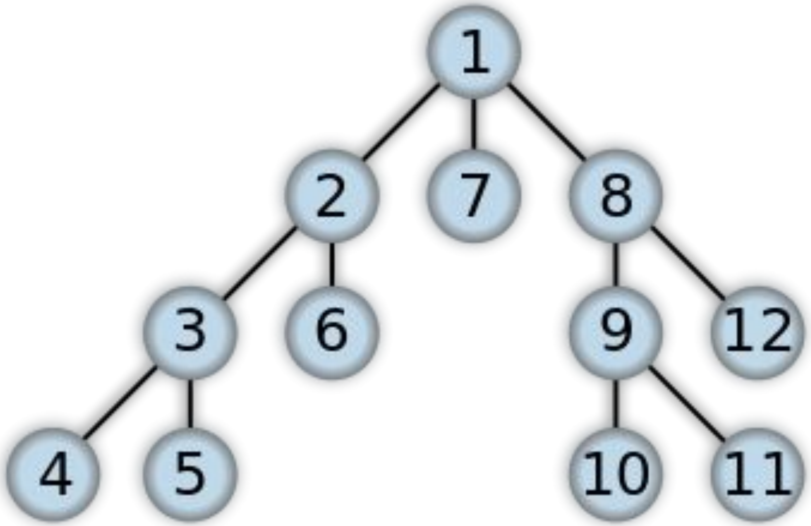
let assembler decide offsets for
(jalr zero, zero, link)

```
// ends is unnest
HEADER"ENDS",ends,
.word    0x000
unnest: …
```

## Why PDP-11 ?

the PiDP-11 is a replica of the PDP-11/70, with a Raspberry Pi running the simh simulator for PDP-11/70, in a Linux Debian.

# deep-first search



Compound words (aka twig)

1, 2, 3, 8, 9

Primitive words (aka leaf)

4, 5, 6, 7, 10, 11, 12

https://en.wikipedia.org/wiki/Depth-first_search

# Primitive Sequences

| | |
|---|---|
| docol | call |
| docon | lit @ |
| dovar | lit |
| douser | useraddr |
| dodefer | lit @ exec |
| dofield | lit + |
| dodoes | lit call |

https://www.academia.edu/105385974/Primitive_sequences_in_general_purpose_Forth_programs