CODE BEAM SF MAR 2018

UNDERSTANDING ERLANG TERMS

Boshan Sun (SUBSPLASH)

MYTH

- Tail-recursive functions are much faster than body-recursive functions

HOW TO IMPLEMENT ERLANG'S TYPE SYSTEM?

- Dynamic typing

INFORMATION = BITS + CONTEXT

```
+-----+-----+-----+-----+-----+-----+-----+-----+
|0x68 |0x69 |0x6c |0x6c |0x6f |0x00 |0x00 |0x00 |
+-----+-----+-----+-----+-----+-----+-----+-----+
|0x100|0x101|0x102|0x103|0x104|0x105|0x106|0x107|
+-----+-----+-----+-----+-----+-----+-----+-----+

+-----+-----+-----+-----+-----+-----+-----+-----+
|  h  |  e  |  l  |  l  |  o  | \0  | \0  | \0  |
+-----+-----+-----+-----+-----+-----+-----+-----+
|0x100|0x101|0x102|0x103|0x104|0x105|0x106|0x107|
+-----+-----+-----+-----+-----+-----+-----+-----+

+-----+-----+-----+-----+-----+-----+-----+-----+
|   26984   |   27756   |    111    |     0     |
+-----+-----+-----+-----+-----+-----+-----+-----+
|0x100|0x101|0x102|0x103|0x104|0x105|0x106|0x107|
+-----+-----+-----+-----+-----+-----+-----+-----+

+-----+-----+-----+-----+-----+-----+-----+-----+
|       1819044200      |          111          |
+-----+-----+-----+-----+-----+-----+-----+-----+
|0x100|0x101|0x102|0x103|0x104|0x105|0x106|0x107|
+-----+-----+-----+-----+-----+-----+-----+-----+
```

ERLANG'S BUILDING BLOCK(PARTIALLY)

- Numbers
  - 1, 2, 100
  - 1.0, 3.14
- Atoms
  - ok, true, false
- Tuples
  - {}, {1, 2, 3}, {ok, 100}
- Lists
  - [], [1, 2, 3]
- Maps
  - #{name => “Jon Snow”, job => “King”}
- Binaries
  - <<“hello”>>, <<1, 2, 3>>

A NAIVE IMPLEMENTATION

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxxx000   integer

xxxxxxxx xxxxxxxx xxxxxxxx xxxxx001   float

xxxxxxxx xxxxxxxx xxxxxxxx xxxxx010   atom

xxxxxxxx xxxxxxxx xxxxxxxx xxxxx011   tuple

xxxxxxxx xxxxxxxx xxxxxxxx xxxxx100   list

xxxxxxxx xxxxxxxx xxxxxxxx xxxxx101   map

xxxxxxxx xxxxxxxx xxxxxxxx xxxxx110   binary

xxxxxxxx xxxxxxxx xxxxxxxx xxxxx111   *not in use
```

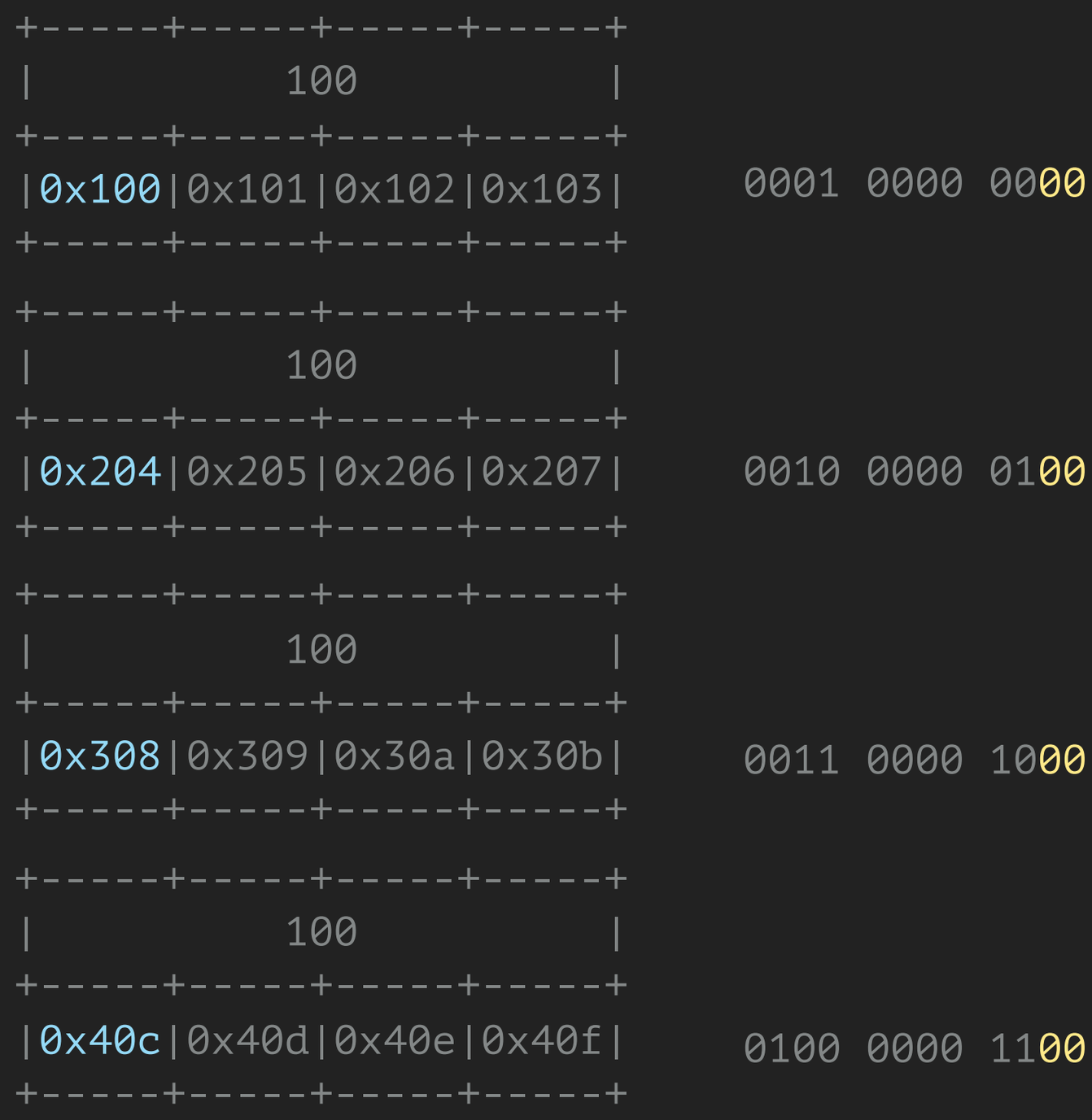
ERLANG TERM

```
/* erts/emulator/beam/sys.h */
typedef unsigned long Eterm erts_align_attribute(sizeof(long));
```

```
                                        xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx 32-bits
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx 64-bits
```

DATA ALIGNMENT PROPERTY

```
int i = 100;
printf("%p", &i);
```



A STAGED TAG SCHEME FOR ERLANG

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx01    list

xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx10    boxed
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx00    header

xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx11    immediate 1
xxxxxxxx xxxxxxxx xxxxxxxx xxxx0011    pid
xxxxxxxx xxxxxxxx xxxxxxxx xxxx0111    port
xxxxxxxx xxxxxxxx xxxxxxxx xxxx1111    small int

xxxxxxxx xxxxxxxx xxxxxxxx xxxx1011    immediate 2
xxxxxxxx xxxxxxxx xxxxxxxx xx001011    atom
xxxxxxxx xxxxxxxx xxxxxxxx xx011011    catch
11111111 11111111 11111111 11111011    nil
```

BOXED HEADER

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx00   header

xxxxxxxx xxxxxxxx xxxxxxxx xx000000   tuple
xxxxxxxx xxxxxxxx xxxxxxxx xx000100   binary match context
xxxxxxxx xxxxxxxx xxxxxxxx xx001000   pos big int
xxxxxxxx xxxxxxxx xxxxxxxx xx001100   neg big int
xxxxxxxx xxxxxxxx xxxxxxxx xx010000   reference
xxxxxxxx xxxxxxxx xxxxxxxx xx010100   function
xxxxxxxx xxxxxxxx xxxxxxxx xx011000   float
xxxxxxxx xxxxxxxx xxxxxxxx xx011100   export
xxxxxxxx xxxxxxxx xxxxxxxx xx100000   refc binary
xxxxxxxx xxxxxxxx xxxxxxxx xx100100   heap binary
xxxxxxxx xxxxxxxx xxxxxxxx xx101000   sub binary
xxxxxxxx xxxxxxxx xxxxxxxx xx101100   *not used
xxxxxxxx xxxxxxxx xxxxxxxx xx110000   external pid
xxxxxxxx xxxxxxxx xxxxxxxx xx110100   external port
xxxxxxxx xxxxxxxx xxxxxxxx xx111000   external reference
xxxxxxxx xxxxxxxx xxxxxxxx xx111100   map
```

IMMEDIATE 1

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx11    immediate 1

xxxxxxxx xxxxxxxx xxxxxxxx xxxx1111    small int
xxxxxxxx xxxxxxxx xxxxxxxx xxxx0011    pid
xxxxxxxx xxxxxxxx xxxxxxxx xxxx0111    port
```

IMMEDIATE 1

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx11    immediate 1

xxxxxxxx xxxxxxxx xxxxxxxx xxxx1111    small int
xxxxxxxx xxxxxxxx xxxxxxxx xxxx0011    pid
xxxxxxxx xxxxxxxx xxxxxxxx xxxx0111    port
```

SMALL INT

xxxxxxxx xxxxxxxx xxxxxxxx xxxx1111

xxxxxxxx xxxxxxxx xxxxxxxx xxxx1111 32-bits

xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxx1111 64-bits

01111111 11111111 11111111 11111111 TMAX 32

10000000 00000000 00000000 00001111 TMIN 32

-134,217,728 - 134,217,727

01111111 11111111 11111111 11111111 11111111 11111111 11111111 11111111 TMAX 64

10000000 00000000 00000000 00000000 00000000 00000000 00000000 00001111 TMIN 64

-576,460,752,303,423,488 - 576,460,752,303,423,487

IMMEDIATE 2

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxx1011    immediate 2

xxxxxxxx xxxxxxxx xxxxxxxx xx001011    atom
xxxxxxxx xxxxxxxx xxxxxxxx xx011011    catch
11111111 11111111 11111111 11111011    nil
```

IMMEDIATE 2

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxx1011    immediate 2

xxxxxxxx xxxxxxxx xxxxxxxx xx001011    atom
xxxxxxxx xxxxxxxx xxxxxxxx xx011011    catch
11111111 11111111 11111111 11111011    nil
```

ATOM

```
                                    xxxxxxxx xxxxxxxx xxxxxxxx xx001011

                                    xxxxxxxx xxxxxxxx xxxxxxxx xx001011 32-bits
 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xx001011 64-bits
```

```
                                    11111111 11111111 11111111 11001011  MAX 32
                                                                67,108,863

 00000000 00000000 00000000 00011111 11111111 11111111 11111111 11001011  MAX 64
                                                             2,147,483,647
```

- Default 2^20 = 1,048,576
- Min 8192

IMMEDIATE 2

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxx1011    immediate 2

xxxxxxxx xxxxxxxx xxxxxxxx xx001011    atom
xxxxxxxx xxxxxxxx xxxxxxxx xx011011    catch
11111111 11111111 11111111 11111011    nil
```

NIL

```
                                    11111111 11111111 11111111 11011011

                                    11111111 11111111 11111111 11001011 32-bits
 11111111 11111111 11111111 11111111 11111111 11111111 11111111 11001011 64-bits
```

- []

- Not `nil` in Elixir

PRIMARY TAG

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx01   list

xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx10   boxed
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx00   header
```

PRIMARY TAG

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx01   list

xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx10   boxed
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx00   header
```

LIST(CONS)

- car
- cdr
- [car | cdr]

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx01
```

```
[1]
0x100   0x000000000000001f   car: 1
0x108   0xfffffffffffffffb   cdr: []
```

```
[1,2]
0x200   0x000000000000002f   car: 2
0x208   0xfffffffffffffffb   cdr: []
0x210   0x000000000000001f   car: 1
0x218   0x0000000000000201   cdr: [2]
```

```
[]
0x300   0xfffffffffffffffb
```

PRIMARY TAG

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx01   list

xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx10   boxed
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx00   header
```

BOXED

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx10
```

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx10
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx00
```

BOXED HEADER

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx00   header

xxxxxxxx xxxxxxxx xxxxxxxx xx000000   tuple
xxxxxxxx xxxxxxxx xxxxxxxx xx000100   binary match context
xxxxxxxx xxxxxxxx xxxxxxxx xx001000   pos big int
xxxxxxxx xxxxxxxx xxxxxxxx xx001100   neg big int
xxxxxxxx xxxxxxxx xxxxxxxx xx010000   reference
xxxxxxxx xxxxxxxx xxxxxxxx xx010100   function
xxxxxxxx xxxxxxxx xxxxxxxx xx011000   float
xxxxxxxx xxxxxxxx xxxxxxxx xx011100   export
xxxxxxxx xxxxxxxx xxxxxxxx xx100000   refc binary
xxxxxxxx xxxxxxxx xxxxxxxx xx100100   heap binary
xxxxxxxx xxxxxxxx xxxxxxxx xx101000   sub binary
xxxxxxxx xxxxxxxx xxxxxxxx xx101100   *not used
xxxxxxxx xxxxxxxx xxxxxxxx xx110000   external pid
xxxxxxxx xxxxxxxx xxxxxxxx xx110100   external port
xxxxxxxx xxxxxxxx xxxxxxxx xx111000   external reference
xxxxxxxx xxxxxxxx xxxxxxxx xx111100   map
```

BOXED HEADER

```
xxxxxxxx xxxxxxxx xxxxxxxx xxxxxx00   header

xxxxxxxx xxxxxxxx xxxxxxxx xx000000   tuple
xxxxxxxx xxxxxxxx xxxxxxxx xx000100   binary match context
xxxxxxxx xxxxxxxx xxxxxxxx xx001000   pos big int
xxxxxxxx xxxxxxxx xxxxxxxx xx001100   neg big int
xxxxxxxx xxxxxxxx xxxxxxxx xx010000   reference
xxxxxxxx xxxxxxxx xxxxxxxx xx010100   function
xxxxxxxx xxxxxxxx xxxxxxxx xx011000   float
xxxxxxxx xxxxxxxx xxxxxxxx xx011100   export
xxxxxxxx xxxxxxxx xxxxxxxx xx100000   refc binary
xxxxxxxx xxxxxxxx xxxxxxxx xx100100   heap binary
xxxxxxxx xxxxxxxx xxxxxxxx xx101000   sub binary
xxxxxxxx xxxxxxxx xxxxxxxx xx101100   *not used
xxxxxxxx xxxxxxxx xxxxxxxx xx110000   external pid
xxxxxxxx xxxxxxxx xxxxxxxx xx110100   external port
xxxxxxxx xxxxxxxx xxxxxxxx xx111000   external reference
xxxxxxxx xxxxxxxx xxxxxxxx xx111100   map
```

TUPLE

```
                                    xxxxxxxx xxxxxxxx xxxxxxxx xx000000

{}
0x100    0x0000000000000000

{1}
0x200    0x0000000000000040
0x208    0x000000000000001f    1

{1,2}
0x300    0x0000000000000080
0x308    0x000000000000001f    1
0x310    0x000000000000002f    2
```

MYTH WALKTHROUGH

- Tail-recursive functions are much faster than body-recursive functions

TAIL-RECURSIVE VS BODY-RECURSIVE

```
-module(foo).¬
-export([add1_tail/1, add1_body/1]).¬
¬
add1_tail(List) ->¬
    add1_tail(List, []).¬
¬
add1_tail([], Acc)     -> lists:reverse(Acc);¬
add1_tail([H|T], Acc) -> add1_tail(T, [H+1|Acc]).
¬
add1_body([])     -> [];¬
add1_body([H|T]) -> [H+1|add1_body(T)].¬
```

TAIL-RECURSIVE

```
|                BEAM STACK                |
|            Address |           Contents |
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1af8 | 0x0000000042fcae49 | [1,2,3,4,5]
| 0x0000000015ac1af0 | 0x0000000019ede830 | BEAM PC foo:run1/0 + 0x5
|--------------------|--------------------|
```

```
|--------------------|--------------------|
|--------------------|--------------------|
|            Address |           Contents |
|                H E A P                   |
```

TAIL-RECURSIVE

```
|                BEAM STACK                |
|            Address |           Contents |
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1af8 | 0x0000000042fcae59 | [2,3,4,5]
| 0x0000000015ac1af0 | 0xfffffffffffffffb | []
| 0x0000000015ac1ae8 | 0x000000000000001f | 1
| 0x0000000015ac1ae0 | 0x0000000019ede830 | BEAM PC foo:run1/0 + 0x5
|--------------------|--------------------|
```

```
|--------------------|--------------------|
|--------------------|--------------------|
|            Address |           Contents |
|                H E A P                   |
```

TAIL-RECURSIVE

```
|                BEAM STACK                |
|            Address |           Contents |
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1af8 | 0x0000000042fcae69 | [3,4,5]
| 0x0000000015ac1af0 | 0x0000000015ac13c9 | [2]
| 0x0000000015ac1ae8 | 0x000000000000002f | 2
| 0x0000000015ac1ae0 | 0x0000000019ede830 | BEAM PC foo:run1/0 + 0x5
|--------------------|--------------------|
```

```
|--------------------|--------------------|
| 0x0000000015ac13d0 | 0xfffffffffffffffb | []
| 0x0000000015ac13c8 | 0x000000000000002f | 2
|--------------------|--------------------|
|            Address |           Contents |
|                H E A P                   |
```

TAIL-RECURSIVE

```
|                BEAM STACK                |
|            Address |           Contents |
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1af8 | 0x0000000042fcae79 | [4,5]
| 0x0000000015ac1af0 | 0x0000000015ac13d9 | [3,2]
| 0x0000000015ac1ae8 | 0x000000000000003f | 3
| 0x0000000015ac1ae0 | 0x0000000019ede830 | BEAM PC foo:run1/0 + 0x5
|--------------------|--------------------|
```

```
|--------------------|--------------------|
| 0x0000000015ac13e0 | 0x0000000015ac13c9 | [2]
| 0x0000000015ac13d8 | 0x000000000000003f | 3
| 0x0000000015ac13d0 | 0xfffffffffffffffb | []
| 0x0000000015ac13c8 | 0x000000000000002f | 2
|--------------------|--------------------|
|            Address |           Contents |
|                H E A P                 |
```

TAIL-RECURSIVE

```
|                BEAM STACK                |
|            Address |           Contents |
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1af8 | 0x0000000042fcae89 | [5]
| 0x0000000015ac1af0 | 0x0000000015ac13e9 | [4,3,2]
| 0x0000000015ac1ae8 | 0x000000000000004f | 4
| 0x0000000015ac1ae0 | 0x0000000019ede830 | BEAM PC foo:run1/0 + 0x5
|--------------------|--------------------|
```

```
|--------------------|--------------------|
| 0x0000000015ac13f0 | 0x0000000015ac13d9 | [3,2]
| 0x0000000015ac13e8 | 0x000000000000004f | 4
| 0x0000000015ac13e0 | 0x0000000015ac13c9 | [2]
| 0x0000000015ac13d8 | 0x000000000000003f | 3
| 0x0000000015ac13d0 | 0xfffffffffffffffb | []
| 0x0000000015ac13c8 | 0x000000000000002f | 2
|--------------------|--------------------|
|            Address |           Contents |
|                H E A P                 |
```

TAIL-RECURSIVE

```
|                BEAM STACK                |
|            Address |           Contents |
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1af8 | 0xfffffffffffffffb | []
| 0x0000000015ac1af0 | 0x0000000015ac13f9 | [5,4,3,2]
| 0x0000000015ac1ae8 | 0x000000000000005f | 5
| 0x0000000015ac1ae0 | 0x0000000019ede830 | BEAM PC foo:run1/0 + 0x5
|--------------------|--------------------|
```

```
|--------------------|--------------------|
| 0x0000000015ac1400 | 0x0000000015ac13e9 | [4,3,2]
| 0x0000000015ac13f8 | 0x000000000000005f | 5
| 0x0000000015ac13f0 | 0x0000000015ac13d9 | [3,2]
| 0x0000000015ac13e8 | 0x000000000000004f | 4
| 0x0000000015ac13e0 | 0x0000000015ac13c9 | [2]
| 0x0000000015ac13d8 | 0x000000000000003f | 3
| 0x0000000015ac13d0 | 0xfffffffffffffffb | []
| 0x0000000015ac13c8 | 0x000000000000002f | 2
|--------------------|--------------------|
|            Address |           Contents |
|                H E A P                   |
```

TAIL-RECURSIVE

```
|                BEAM STACK                |
|            Address |           Contents |
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1af8 | 0x0000000015ac1409 | [6,5,4,3,2]
| 0x0000000015ac1af0 | 0x0000000019ede830 | BEAM PC foo:run1/0 + 0x5
|--------------------|--------------------|
```

```
|--------------------|--------------------|
| 0x0000000015ac1410 | 0x0000000015ac13f9 | [5,4,3,2]
| 0x0000000015ac1408 | 0x000000000000006f | 6
| 0x0000000015ac1400 | 0x0000000015ac13e9 | [4,3,2]
| 0x0000000015ac13f8 | 0x000000000000005f | 5
| 0x0000000015ac13f0 | 0x0000000015ac13d9 | [3,2]
| 0x0000000015ac13e8 | 0x000000000000004f | 4
| 0x0000000015ac13e0 | 0x0000000015ac13c9 | [2]
| 0x0000000015ac13d8 | 0x000000000000003f | 3
| 0x0000000015ac13d0 | 0xfffffffffffffffb | []
| 0x0000000015ac13c8 | 0x000000000000002f | 2
|--------------------|--------------------|
|            Address |           Contents |
|                H E A P                   |
```

TAIL-RECURSIVE

BEAM STACK		
Address	Contents	
0x0000000015ac1b08	0x0000000015ac1459	BEAM ACTIVATION RECORD
0x0000000015ac1b00	0x000000001525a148	[2,3,4,5,6]
		BEAM PC normal-process-exit

0x0000000015ac1460	0x0000000015ac1449	[3,4,5,6]
0x0000000015ac1458	0x000000000000002f	2
0x0000000015ac1450	0x0000000015ac1439	[4,5,6]
0x0000000015ac1448	0x000000000000003f	3
0x0000000015ac1440	0x0000000015ac1429	[5,6]
0x0000000015ac1438	0x000000000000004f	4
0x0000000015ac1430	0x0000000015ac1419	[6]
0x0000000015ac1428	0x000000000000005f	5
0x0000000015ac1420	0xfffffffffffffffb	[]
0x0000000015ac1418	0x000000000000006f	6
0x0000000015ac1410	0x0000000015ac13f9	[5,4,3,2]
0x0000000015ac1408	0x000000000000006f	6
0x0000000015ac1400	0x0000000015ac13e9	[4,3,2]
0x0000000015ac13f8	0x000000000000005f	5
0x0000000015ac13f0	0x0000000015ac13d9	[3,2]
0x0000000015ac13e8	0x000000000000004f	4
0x0000000015ac13e0	0x0000000015ac13c9	[2]
0x0000000015ac13d8	0x000000000000003f	3
0x0000000015ac13d0	0xfffffffffffffffb	[]
0x0000000015ac13c8	0x000000000000002f	2

Address	Contents
H E A P	

BODY-RECURSIVE

```
|                BEAM STACK                |
|            Address |           Contents |
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1af8 | 0x0000000042fcae59 | [2,3,4,5]
| 0x0000000015ac1af0 | 0x000000000000001f | 1
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1ae8 | 0x0000000019ede8b0 | BEAM PC foo:run2/0 + 0x5
|--------------------|--------------------|
```

```
|--------------------|--------------------|
|--------------------|--------------------|
|            Address |           Contents |
|                H E A P                   |
```

BODY-RECURSIVE

```
|                BEAM STACK                |
|            Address |           Contents |
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1af8 | 0x000000000000002f | 2
| 0x0000000015ac1af0 | 0x0000000019ede8b0 | BEAM PC foo:run2/0 + 0x5
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1ae8 | 0x0000000042fcae69 | [3,4,5]
| 0x0000000015ac1ae0 | 0x000000000000002f | 2
| 0x0000000015ac1ad8 | 0x0000000019ede000 | BEAM PC foo:add1_body/1 + 0x12
|--------------------|--------------------|
```

```
|--------------------|--------------------|
|--------------------|--------------------|
|            Address |           Contents |
|                H E A P                   |
```

BODY-RECURSIVE

```
|                BEAM STACK                |
|            Address |           Contents |
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1af8 | 0x000000000000002f | 2
| 0x0000000015ac1af0 | 0x0000000019ede8b0 | BEAM PC foo:run2/0 + 0x5
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1ae8 | 0x000000000000003f | 3
| 0x0000000015ac1ae0 | 0x0000000019ede000 | BEAM PC foo:add1_body/1 + 0x12
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1ad8 | 0x0000000042fcae79 | [4,5]
| 0x0000000015ac1ad0 | 0x000000000000003f | 3
| 0x0000000015ac1ac8 | 0x0000000019ede000 | BEAM PC foo:add1_body/1 + 0x12
|--------------------|--------------------|
```

```
|--------------------|--------------------|
|--------------------|--------------------|
|            Address |           Contents |
|                H E A P                   |
```

BODY-RECURSIVE

```
|                BEAM STACK                |
|            Address |           Contents |
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1af8 | 0x000000000000002f | 2
| 0x0000000015ac1af0 | 0x0000000019ede8b0 | BEAM PC foo:run2/0 + 0x5
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1ae8 | 0x000000000000003f | 3
| 0x0000000015ac1ae0 | 0x0000000019ede000 | BEAM PC foo:add1_body/1 + 0x12
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1ad8 | 0x000000000000004f | 4
| 0x0000000015ac1ad0 | 0x0000000019ede000 | BEAM PC foo:add1_body/1 + 0x12
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1ac8 | 0x0000000042fcae89 | [5]
| 0x0000000015ac1ac0 | 0x000000000000004f | 4
| 0x0000000015ac1ab8 | 0x0000000019ede000 | BEAM PC foo:add1_body/1 + 0x12
|--------------------|--------------------|
```

```
|--------------------|--------------------|
|--------------------|--------------------|
|            Address |           Contents |
|                H E A P                   |
```

BODY-RECURSIVE

```
|                BEAM STACK                |
|             Address |            Contents |
|---------------------|---------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1af8  | 0x000000000000002f  | 2
| 0x0000000015ac1af0  | 0x0000000019ede8b0  | BEAM PC foo:run2/0 + 0x5
|---------------------|---------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1ae8  | 0x000000000000003f  | 3
| 0x0000000015ac1ae0  | 0x0000000019ede000  | BEAM PC foo:add1_body/1 + 0x12
|---------------------|---------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1ad8  | 0x000000000000004f  | 4
| 0x0000000015ac1ad0  | 0x0000000019ede000  | BEAM PC foo:add1_body/1 + 0x12
|---------------------|---------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1ac8  | 0x000000000000005f  | 5
| 0x0000000015ac1ac0  | 0x0000000019ede000  | BEAM PC foo:add1_body/1 + 0x12
|---------------------|---------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1ab8  | 0xfffffffffffffffb  | []
| 0x0000000015ac1ab0  | 0x000000000000005f  | 5
| 0x0000000015ac1aa8  | 0x0000000019ede000  | BEAM PC foo:add1_body/1 + 0x12
|---------------------|---------------------|
```

```
|---------------------|---------------------|
|---------------------|---------------------|
|             Address |            Contents |
|                 H E A P                   |
```

BODY-RECURSIVE

BEAM STACK		
Address	Contents	
0x0000000015ac1af8	0x000000000000002f	BEAM ACTIVATION RECORD 2
0x0000000015ac1af0	0x0000000019ede8b0	BEAM PC foo:run2/0 + 0x5
0x0000000015ac1ae8	0x000000000000003f	BEAM ACTIVATION RECORD 3
0x0000000015ac1ae0	0x0000000019ede000	BEAM PC foo:add1_body/1 + 0x12
0x0000000015ac1ad8	0x000000000000004f	BEAM ACTIVATION RECORD 4
0x0000000015ac1ad0	0x0000000019ede000	BEAM PC foo:add1_body/1 + 0x12
0x0000000015ac1ac8	0x000000000000005f	BEAM ACTIVATION RECORD 5
0x0000000015ac1ac0	0x0000000019ede000	BEAM PC foo:add1_body/1 + 0x12
0x0000000015ac1ab8	0x000000000000006f	BEAM ACTIVATION RECORD 6
0x0000000015ac1ab0	0x0000000019ede000	BEAM PC foo:add1_body/1 + 0x12
0x0000000015ac1aa8	0x0000000019ede000	BEAM ACTIVATION RECORD BEAM PC foo:add1_body/1 + 0x12

Address	Contents
H E A P	

BODY-RECURSIVE

```
|                BEAM STACK                |
|            Address |           Contents |
|--------------------|--------------------| BEAM ACTIVATION RECORD
| 0x0000000015ac1b08 | 0x0000000015ac1409 | [2,3,4,5,6]
| 0x0000000015ac1b00 | 0x000000001525a148 | BEAM PC normal-process-exit
|--------------------|--------------------|
```

```
|--------------------|--------------------|
| 0x0000000015ac1410 | 0x0000000015ac13f9 | [3,4,5,6]
| 0x0000000015ac1408 | 0x000000000000002f | 2
| 0x0000000015ac1400 | 0x0000000015ac13e9 | [4,5,6]
| 0x0000000015ac13f8 | 0x000000000000003f | 3
| 0x0000000015ac13f0 | 0x0000000015ac13d9 | [5,6]
| 0x0000000015ac13e8 | 0x000000000000004f | 4
| 0x0000000015ac13e0 | 0x0000000015ac13c9 | [6]
| 0x0000000015ac13d8 | 0x000000000000005f | 5
| 0x0000000015ac13d0 | 0xfffffffffffffffb | []
| 0x0000000015ac13c8 | 0x000000000000006f | 6
|--------------------|--------------------|
|            Address |           Contents |
|                H E A P                   |
```

TAIL-RECURSIVE VS BODY-RECURSIVE

```
-module(foo).¬
-export([add1_tail/1, add1_body/1]).¬
¬
add1_tail(List) ->¬
    add1_tail(List, []).¬
¬
add1_tail([], Acc)     -> lists:reverse(Acc);¬
add1_tail([H|T], Acc) -> add1_tail(T, [H+1|Acc]).
¬
add1_body([])     -> [];¬
add1_body([H|T]) -> [H+1|add1_body(T)].¬
```

MYTH DEMYSTIFY

- Use the version that makes your code cleaner (hint: it is usually the body-recursive version)
- A tail-recursive function that does not need to reverse the list at the end is faster than a body-recursive function

```
map(F, [H|T]) ->
    [F(H)|map(F, T)];
map(F, []) when is_function(F, 1) -> [].
```

RESOURCES

- The Seven Myths of Erlang Performance
  - http://erlang.org/doc/efficiency_guide/myths.html
- A Staged Tag Scheme for Erlang(2000)
  - http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.142.2827
- The Erlang Type System and Tags(The BEAM Book)
  - https://happi.github.io/theBeamBook/#CH-TypeSystem
- Data Types Memory Layout(BEAM-WISDOM)
  - http://beam-wisdoms.clau.se/en/latest/indepth-memory-layout.html
- Erlang/OTP source code
  - https://github.com/erlang/otp/blob/master/erts/emulator/beam/erl_term.h
- ETerm library
  - https://github.com/sunboshan/eterm

THANK YOU

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