Multi-ML: Programming Multi-BSP Algorithms in ML

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Ocaml : a ML language

Strengths of Ocaml

- A functionnal programming language

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- A functionnal programming language
- A powerful type system
- User-definable algebraic data types and pattern matching
- Automatic memory management
- Efficient native code compilers

Syntaxe overview

```
# let f = fun x -> "Hello "^(string_of_int x) in
  let lst = [0;1;2;3] in
  List.map f lst;;
- : string list = ["Hello 0"; "Hello 1"; "Hello 2"; "Hello 3"]

# let pair = ([0;1;2;3],true);;
val pair : int list * bool = ([0; 1; 2; 3], true)

# type 'a list =
   Nil
   | Node of 'a*'a list ;;
type 'a list = Nil | Node of 'a * 'a list
```

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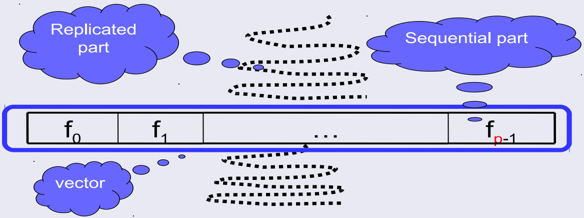
Main idea

Parallel data structure ⇒ vectors:



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Synchronous primitives

- **proj** : $\langle x_0, \ldots, x_{\mathbf{p}-1}\rangle \mapsto (\mathbf{fun}\ i \rightarrow x_i)$
- **put** : $\langle f_0, \ldots, f_{\mathbf{p}-1}\rangle \mapsto \langle(\mathbf{fun}\ i \rightarrow f_i\ 0), \ldots, (\mathbf{fun}\ i \rightarrow f_i\ (\mathbf{p}-1))\rangle$

Code example

For a BSP machine with 3 processors:

```
# let vec = ≪ "Hello␣" ≫ ;;
val vec : string par = <"Hello␣", "Hello␣", "Hello␣">
# let vec2 = ≪ $vec$^(string_of_int $pid$) ≫ ;;
val vec2 : string par = <"Hello␣0", "Hello␣1", "Hello␣2">
# let totex v = List.map (proj v) procs;;
val totex : 'a Bsml.par → 'a list = <fun>
# totex vec2;;
— : string list = ["Hello0"; "Hello1"; "Hello2"]
```

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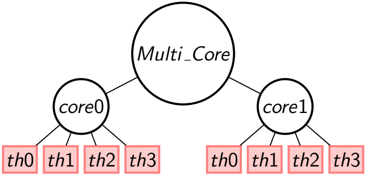

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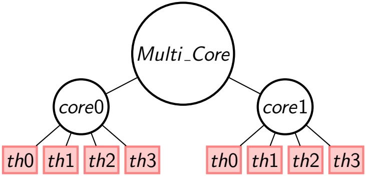
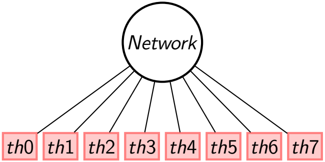
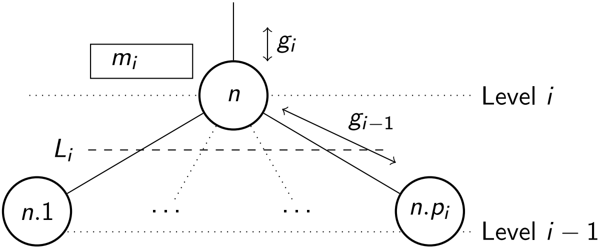


BSP



Execution model

A level i superstep is:



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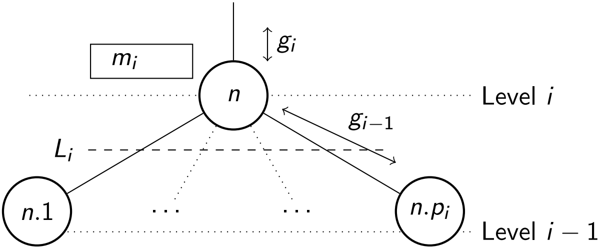
- Level $i-1$ executes code independantly



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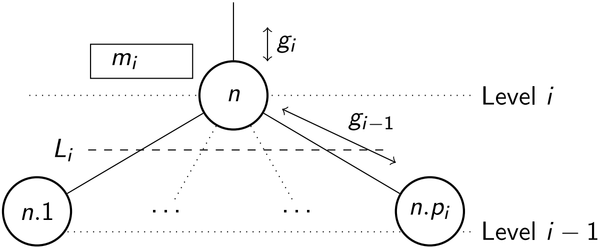

Execution model

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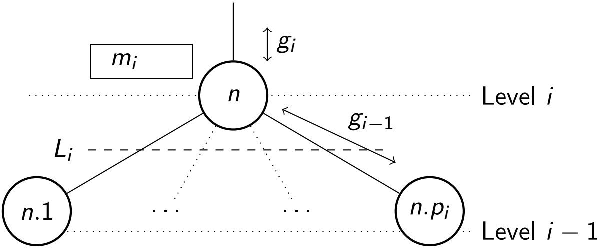
- Level $i-1$ executes code independantly
- Exchanges informations with the m_i memory
- Synchronises



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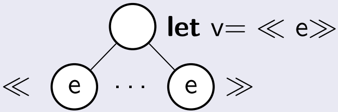

Recursion structure

let multi f [args] =
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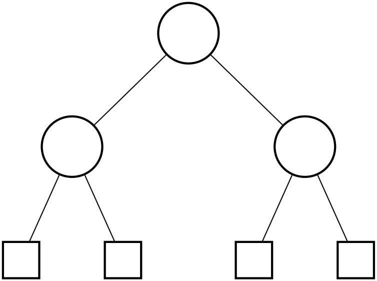

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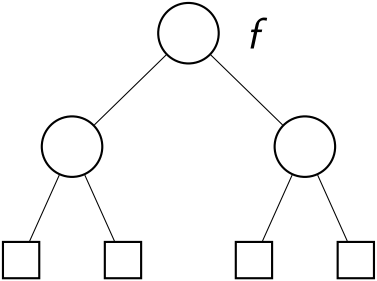

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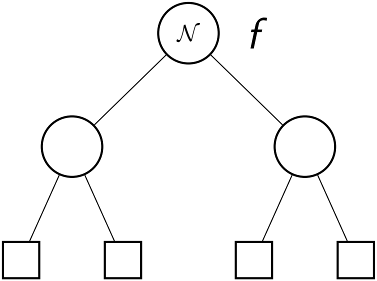

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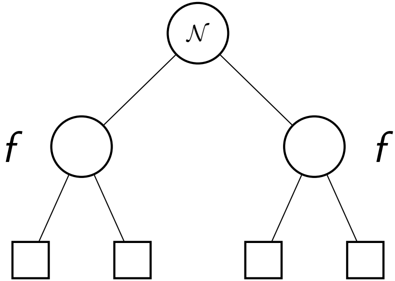

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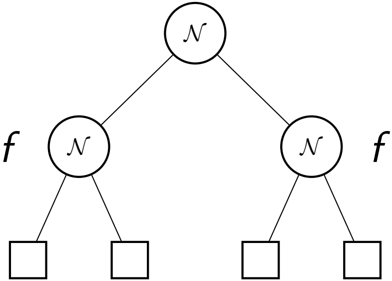

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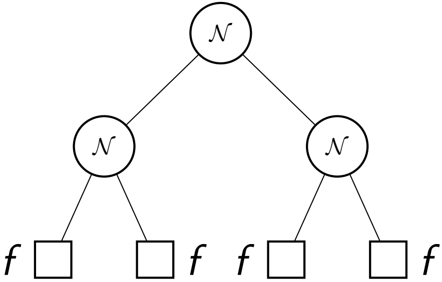

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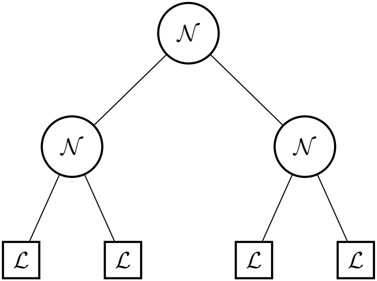

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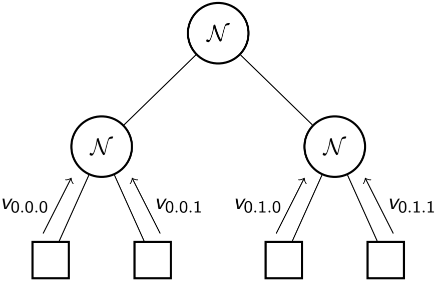

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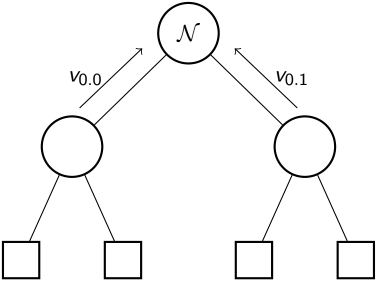

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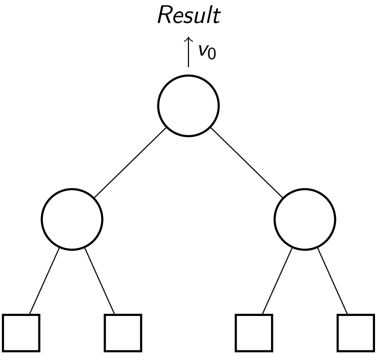

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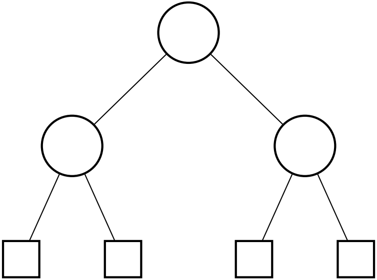

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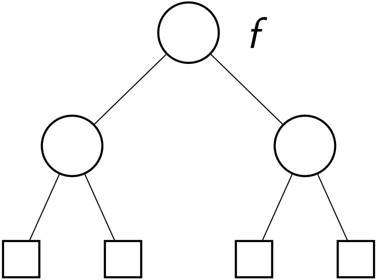

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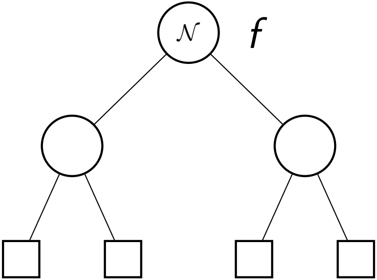

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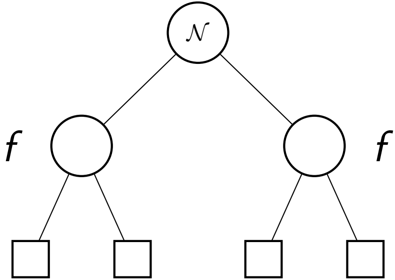

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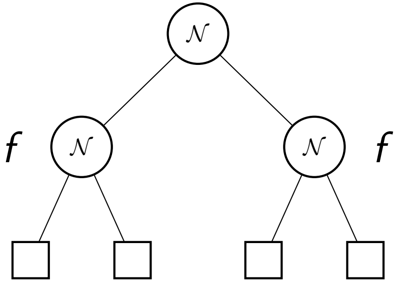

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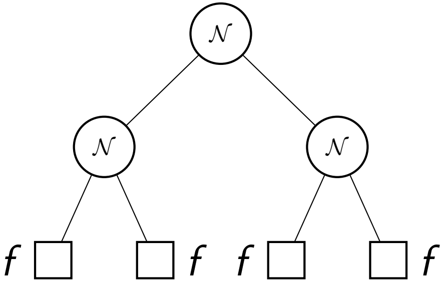

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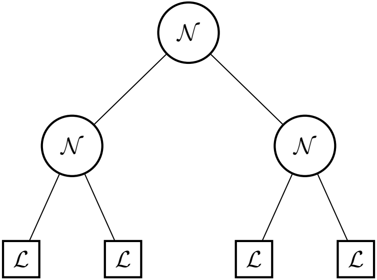

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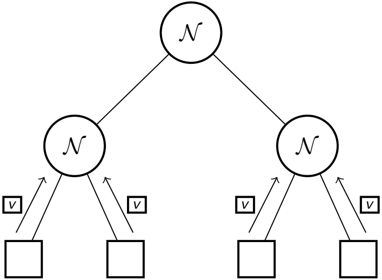

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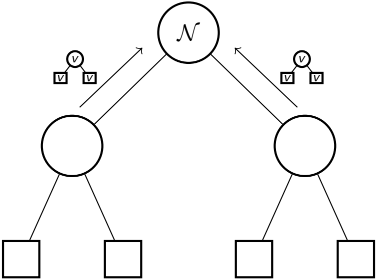

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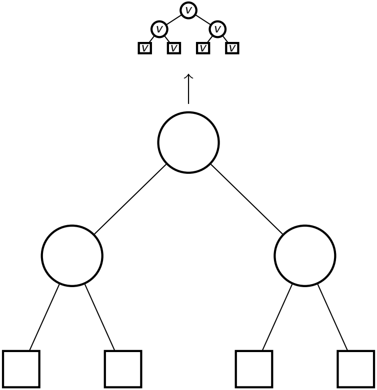

Primitives

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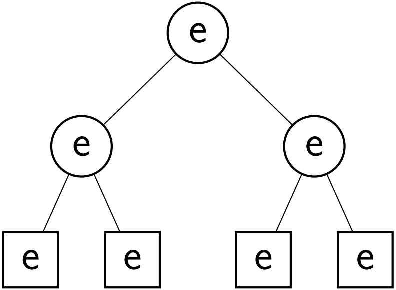

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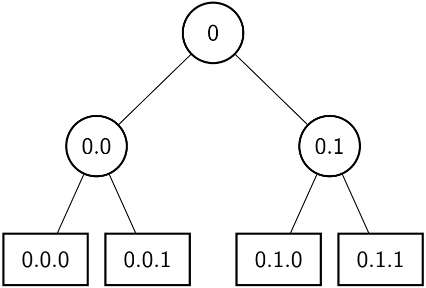

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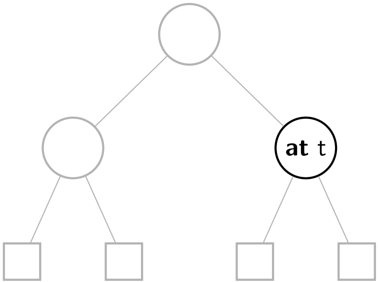

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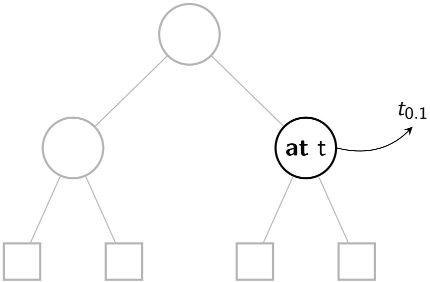

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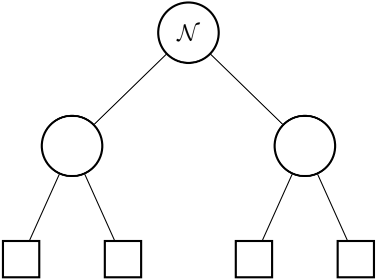

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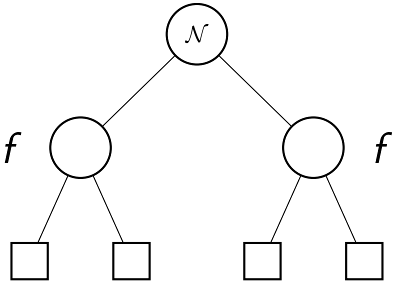

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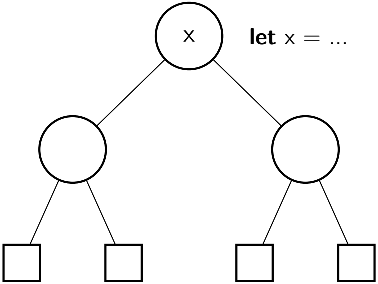

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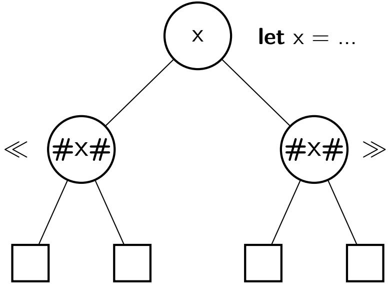

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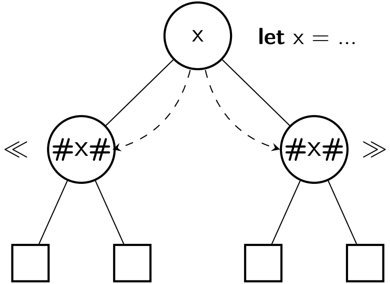

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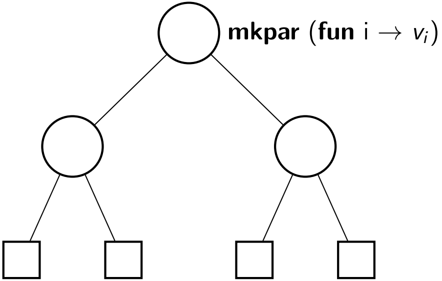
- ≪...f...≫
- #×#
- **mkpar** f



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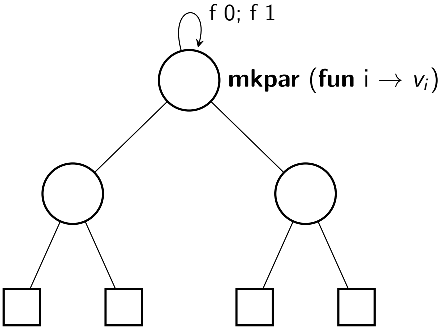
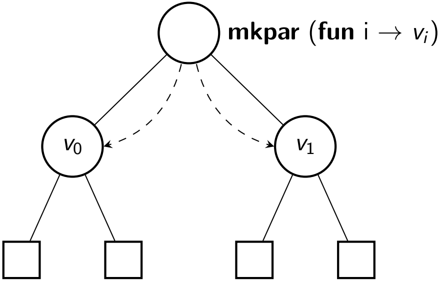
- **#**×**#**
- **mkpar** f



Primitives

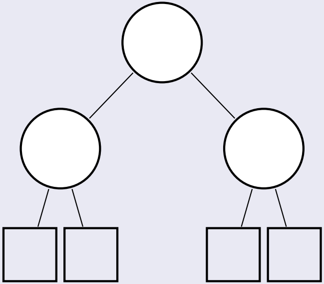
Summary:

- §e§
- **gid**
- **at**
- ≪...f...≫
- **#**×**#**
- **mkpar** f



Code example

Keep the intermediate results of the sum:



let multi tree sum_list l =
  where node =
    let v = **mkpar** (**fun** i → split i l) **in**
    let rc = ≪ sum_list \$v\$≫ **in**
    let s = sumSeq (flatten ≪ **at** \$rc\$≫) **in**
    (rc,s)
  where leaf =
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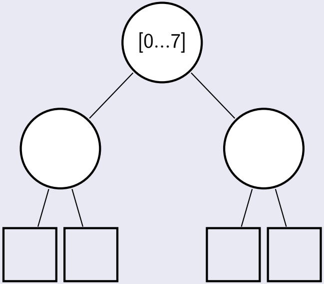

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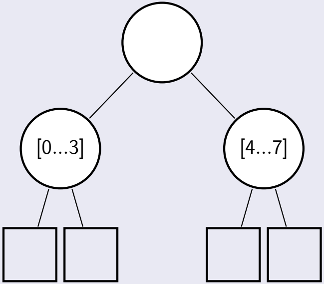

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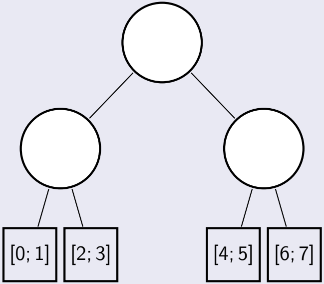

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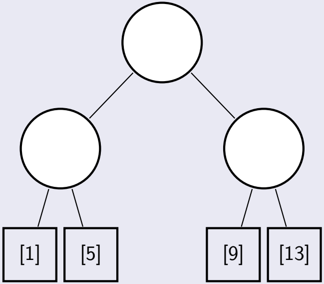


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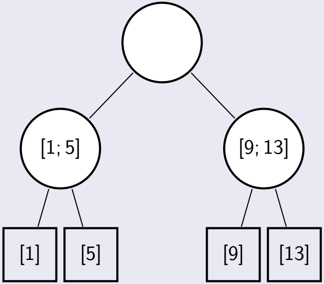


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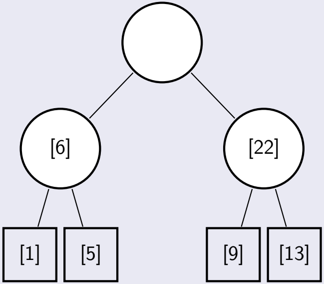


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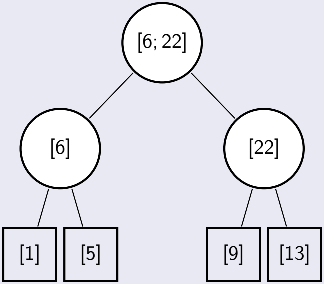

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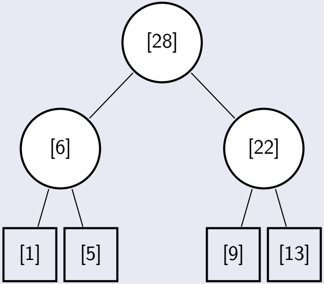


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Semantics

Formal definition of a core-languge

Useful for:

- Study of properties
- Proof of programs/compiler/typing rules

Currently

- Inductive big-step: confluent
- Co-inductive: mutually exclusive

Typing

Purely Constraint-Based system : PCB(X)

- Constraint based
- Extension of DM's type system
- Easy to extend
- Related to HM(X)

MULTI-ML type extension

- Add parallel constructions
- Introduce locality (s, ℓ, b and m) using effects
- Reject nested vectors
- Concistency

Implementation

Sequential simulator

- OCAML-like toplevel
- Test and debug
- Tree sturcture
- Hash tables to represent memories

```
#let multi tree f n =
 | where node =
 | | let r =≪f ($pid$ + #n# + 1) ≫ in
 | | | (r,(gid^"=>"^n))
 | where leaf=
 | | (gid^"=>"^n);;

— : val f : int→string tree = <multi-fun>
#(f 0)
o "0→ 0"
|
−−o "0.0→ 1"
| | −→ "0.0.0→ 2"
| | −→ "0.0.1→ 3"
−−o "0.1→ 2"
| | −→ "0.1.0→ 3"
| | −→ "0.1.1→ 4"
```

Distributed implementation

Our approach

Distributed implementation

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- Modular

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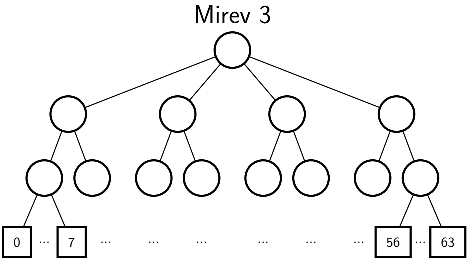

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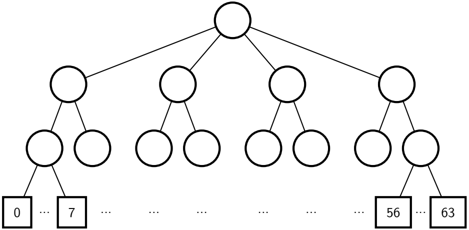

Results

	100_000		500_000		1_000_000	
	MULTI-ML	BSML	MULTI-ML	BSML	MULTI-ML	BSML
8	0.7	1.8	22.4	105.0	125.3	430.7
64	0.3	0.3	1.3	8.7	4.1	56.1
128	0.5	0.45	2.1	5.2	4.7	24.3

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Current/Future work

- Optimise MPI implementation
- Type system for MULTI-ML
- Real life benchmarks

Merci !

Any questions ?