Multi-BSP Programming à la ML

MBSML

Victor Allombert
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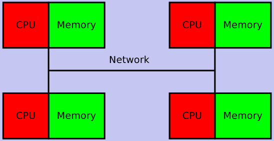
Frédéric Gava - Julien Tesson

Laboratory of **A**lgorithms, **C**omplexity and **L**ogic (LACL)
Université Paris Est

Outline

Parallel Architectures

Distributed computing



Clusters

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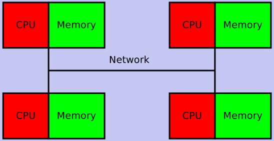

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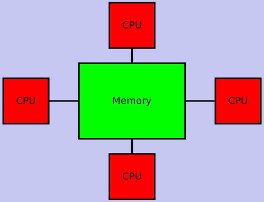

Multi-core

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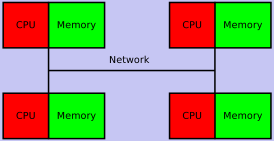

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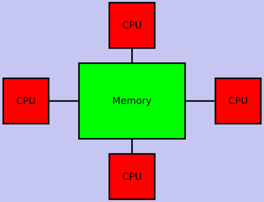

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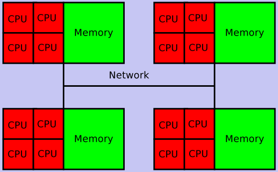
Hybrid model



(Parallel) Software Errors

Risks

- Over-consumption
- Erroneous results

Typical bugs

	Distributed	Shared memory
Deadlocks:		

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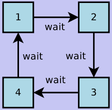

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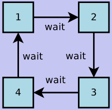

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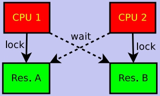

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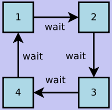

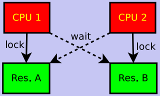

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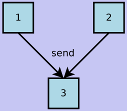

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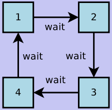

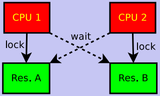

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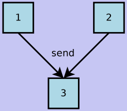

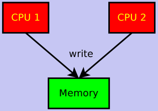

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Considered solutions

1. Well structured parallelism
2. Design a high-level language for "hybrid architectures"
3. Software-hardware bridging model ⇒ Portability, scalability

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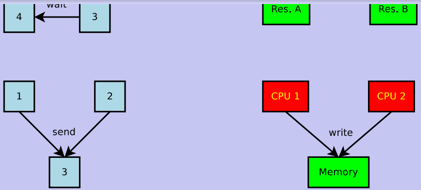

Outline

Bridging Model: Bulk Synchronous Parallelism (BSP)

The BSP computer

Defined by:

- **p** pairs CPU/memory
- Communication network (**g**)
- Synchronisation unit (**L**)
- Super-steps execution

Properties:

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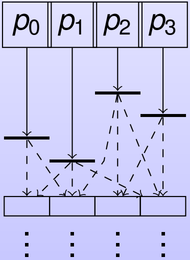

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barrier ($\oplus$**L**)

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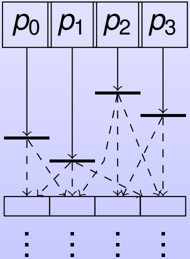

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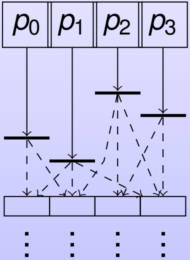

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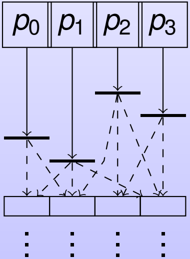

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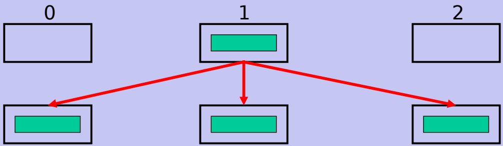
next super-step

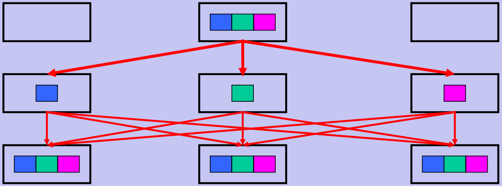
Examples: broadcasting a values

Direct broadcast (one super-step)



Cost $\equiv \mathbf{p} \times \mathbf{g} \times n \quad + \quad \mathbf{L}$

Broadcast with two super-steps



Cost $\equiv 2 \times \mathbf{g} \times n \quad + \quad 2 \times \mathbf{L}$

The BSML Language

BSML

- Explicit BSP programming with a functional approach
- Based upon ML; Implemented over OCaml
- Formal semantics (confluent) → Coq

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- Four primitives ⟹ simple semantics

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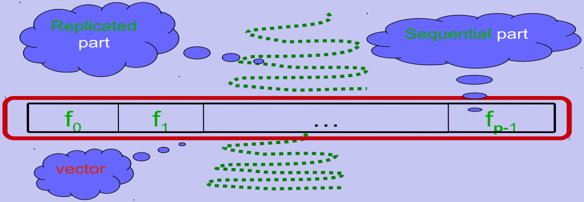
Parallel data structure $\Rightarrow$ vectors:



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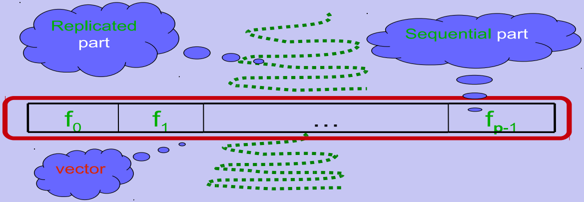

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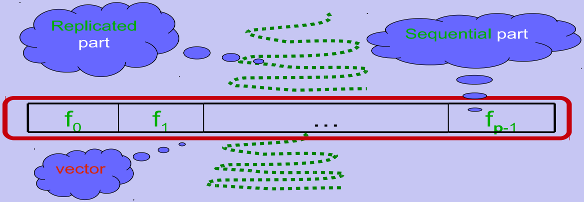

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- **proj**: $\langle x_0, \ldots, x_{p-1} \rangle \mapsto \begin{array}{c} x_0 \\ \vdots \\ x_{p-1} \end{array}$
- **put**: $\langle f_0, \ldots, f_{p-1} \rangle \mapsto \left\langle \begin{array}{ccc} f_0\ 0 & \ldots & f_0\ (p-1) \\ \vdots & & \vdots \\ f_{p-1}\ 0 & \ldots & f_{p-1}\ (p-1) \end{array} \right\rangle$

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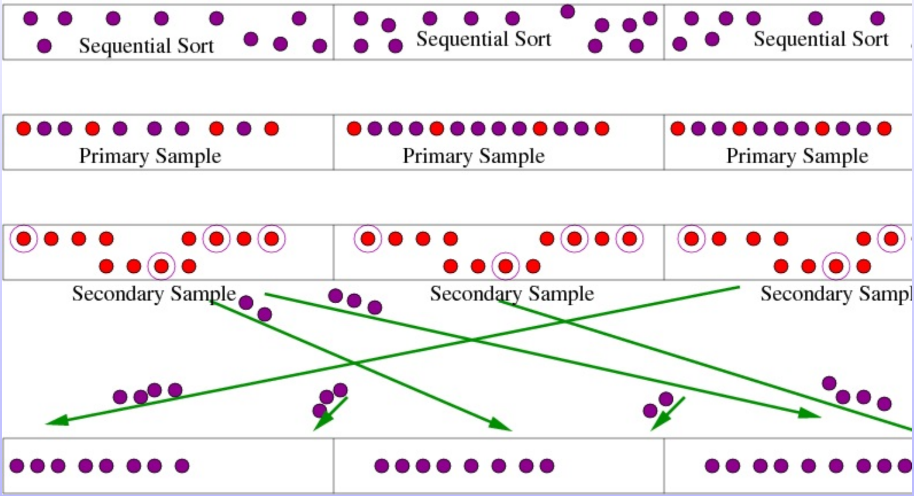
Parallel Sorting by Regular Sampling (PSRS)



Example : PSRS

```
(* psrs: int par → 'a list → 'a list *)
let psrs lvlengths lv =
    (* super−step 1(a): local sorting *)
  let locsort = ≪ List.sort compare $lv$ ≫ in

    (* super−step 1(b): selection of the primary samples *)
  let regsampl = ≪ extract_n P $lvlengths$ $locsort$ ≫ in

    (* super−step 2(a): total exchange of the primary samples;*)
  let glosampl = List.sort compare (proj regsampl) in

    (* super−step 2(b): selection of the secondary samples *)
  let pivots = extract_n P (P*(P−1)) glosampl in

    (* super−step 2(c) : building the communicated lists of values *)
  let comm = ≪ slice_p $locsort$ pivots ≫ in

   (* super−step 3: sended them and merging of the received values *)
  let recv = put ≪ List.nth $comm$ ≫ in
    ≪ p_merge P (List.map $recv$ procs_list) ≫
```

Advantages and Drawbacks

Advantages

- Easy to learn
- "All" OCaml codes can be used
- Easy to get a BSML code from a BSP algorithm
- Pure functional semantics $\rightarrow$ Coq

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Drawbacks

- Complex type system to forbid
  - Nested vectors (**let** v=≪ ...≫ **in** ≪ v≫)
  - Replicated inconsistency (**if** rnd() **then** sync();0 **else** 0)
  - Data-race using side effects (≪ **if** pid=0 **then** v:=2≫)
- Hierarchical architecture as a flat one
- Congestion using network

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What is Multi-BSP? (Valiant)

1. A tree structure with nested components
2. Where nodes have a storage capacity
3. And leaf are homogenous processors

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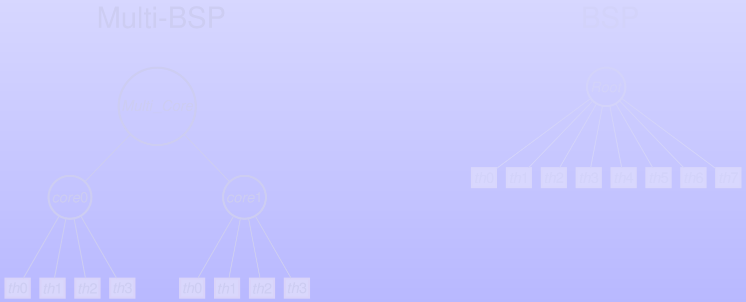

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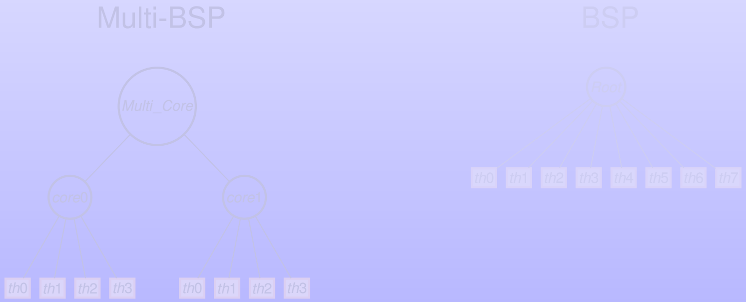

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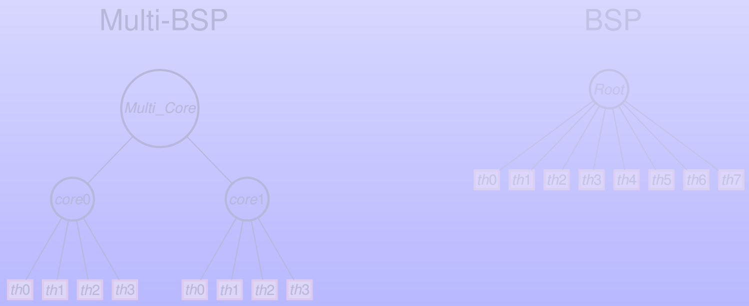

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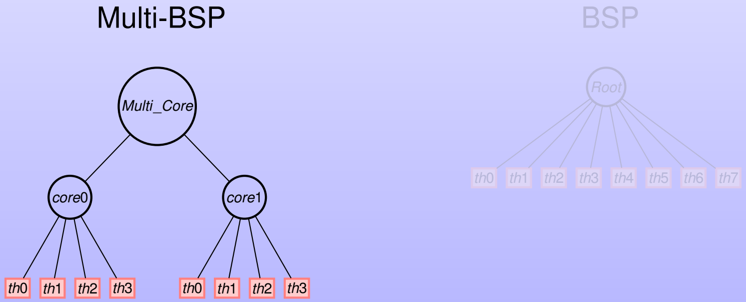

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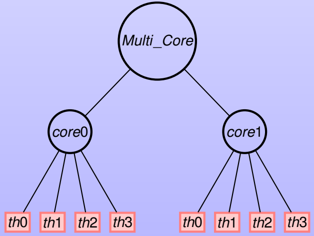
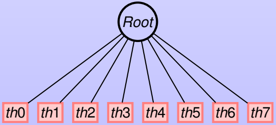


BSP



Multi-BSP Model (2)

Cost model

A d depth tree is specified by $4 \times d$ parameters:

- **p** : Number of sub-components
- **m** : Available memory at a level
- **g** : Bandwidth with the upper level
- **L** : Synchronisation

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Example: 16 quad-chips with octo-cores

- Level 4 ($\mathbf{p}=16, \mathbf{g}=\infty, \mathbf{L}=1000, \mathbf{m}=16\,Tb$) (RAM/IO)
- Level 3 ($\mathbf{p} = 4, \mathbf{g} = 150, \mathbf{L} = 100, \mathbf{m} = 64\,Gb$) (RAM)
- Level 2 ($\mathbf{p} = 8, \mathbf{g} = 5, \mathbf{L} = 10, \mathbf{m} = 2\,Mb$) (L2 cache)
- Level 1 ($\mathbf{p} = 1, \mathbf{g} = 1, \mathbf{L} = 1, \mathbf{m} = 8\,Kb$) (L1 cache)

Multi-BSP Model (3)

Execution model

At a level i, a super-step is:

- Each component at level $i-1$ does its own super-steps
- Then each copies some data to the memory at level i
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Advantages and drawbacks

- Implicit subgroup synchronisation
- Recursive decomposition of problems
- Harder to design/cost some algorithms

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Syntaxic construction

let multi f [args] =
 let cst = CodeOCaml
 where node [args] = CodeBSML ...
 $\ll$ f args $\gg$
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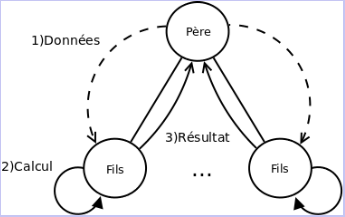

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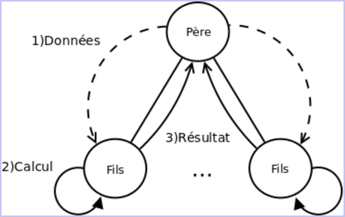

Limitations and differences

- Nodes are implicit computation units
- Horizontal communications between level components
- Garbage collector ⇒ no L1, L2 caches.

Multi-BSML Language (2)

Semantics of multi

- BSML code to distribute values
- $\langle\langle \ldots \rangle\rangle$ and **proj**; level changing
- Mutual recursive functions of standard OCaml values
- (Formal) Big-steps $\Longleftrightarrow$ small-steps for a mini-Multi-BSML

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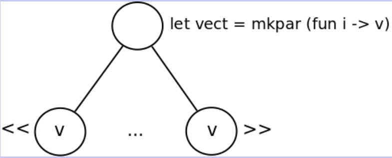
Copy memory values and distribution of values

- **let** x = 1 **in** $\ll$ #x# + 1$\gg$
- **mkpar** (**fun** i → e)

  $\mapsto \langle\ v_0, \ldots, v_{\mathbf{p}-1}\ \rangle$

  where $(e\ i) \mapsto v_i$



Example : Sum Of The Elements Of A List

```
let multi sum_list l =

   where node l =
     let v = mkpar (fun i → split i l) in
      sumSeq (flatten ≪ sum_list $v$ ≫ ) (* flatten uses a proj *)
                                          (* sumSeq is List.fold_left *)
   where leaf l = sumSeq l

 in ... (sum_list lst) ...
```

Multi With Tree Construction

Goals

- Keep values on each node and leaf
- To program multiple phases of multi

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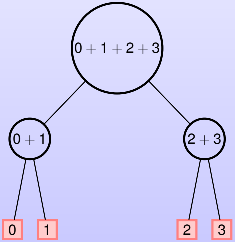
Extension

- finally; pushes up a value and keeps a value
- If the recursive calls generates partial trees ⇒ to raise exceptions “à la BSML”

Example

Keep the intermediate results of the sum




```
let multi sum_list l =

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    let v = mkpar (fun i → split i l) in
    let s = sumSeq (flatten ≪ sum_list $v$ ≫ ) in
     finally ~up:s ~keep:s

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Semantics

Useful semantics

- $\Downarrow$ Big step semantic (with costs)
- $\Downarrow^{co}$ Coinductive big step semantic
- $\rightarrow$ Small step semantic with explicit substitutions (and costs)
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For debugging and toplevel

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- A global tree of Hashtables to represent the memories

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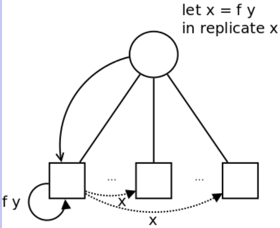

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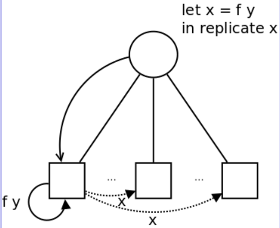

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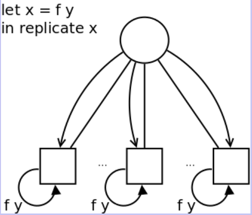

Outline

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