Multi-BSML, une approche à la ML pour la programmation Multi-BSP

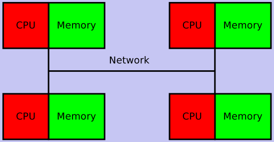
Victor Allombert & Frédéric Gava & Julien Tesson

Laboratory of **A**lgorithms, **C**omplexity and **L**ogic (LACL)
University of Paris-East

Outline

Parallel Architectures

Distributed computing



Clusters

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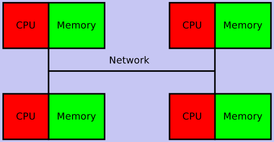
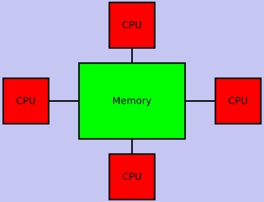


Clusters

Shared memory



Multi-core

Parallel Architectures

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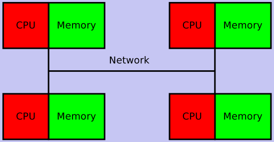

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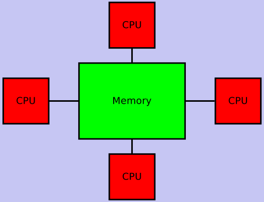
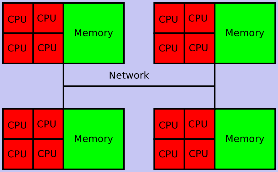


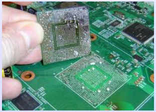
Multi-core

Hybrid model



"Think Parallel or Perish"

GPU



Phone

Tablet

Laptop

PC

Cluster

Supercomputer:

(Parallel) Software Errors

Risks

- Over-consumption
- Erroneous results

Typical bugs

	Distributed	Shared memory
Deadlocks:		

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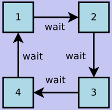

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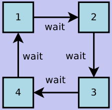

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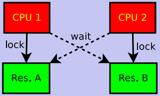

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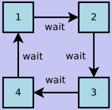

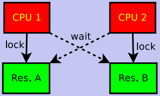

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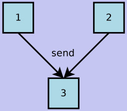

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Distributed | Shared memory

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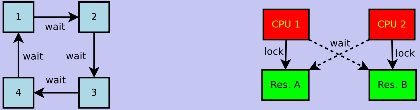

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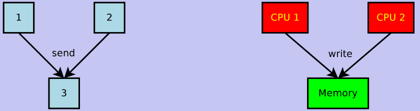

(Parallel) Software Errors

Risks

- Over-consumption
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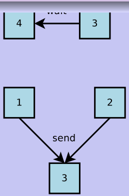
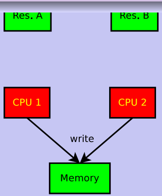
Considered solutions

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





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Why Structured Parallelism?

Safety, debugging and verification

Reasoning about cost

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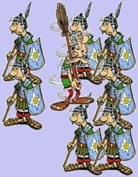

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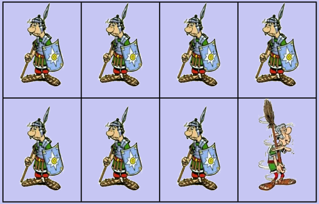

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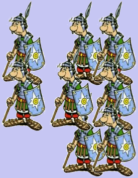

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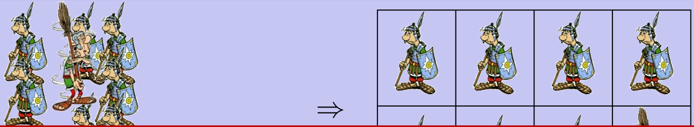

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"*Send-receive considered harmful*" (Sergei GORLATCH)

1. Distributed extension of a functional language;
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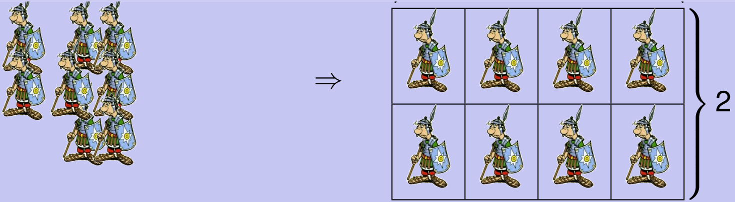

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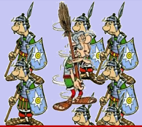

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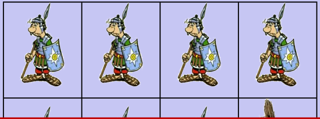

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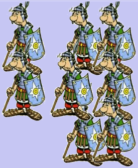

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Outline

Bridging Model: Bulk Synchronous Parallelism (BSP)

The BSP computer

Defined by:

- **p** pairs CPU/memory
- Communication network
- Synchronisation unit
- Super-steps execution

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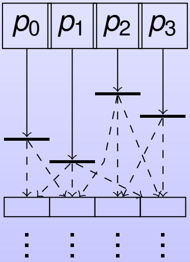

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communication

barrier

next super-step

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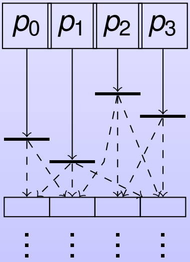

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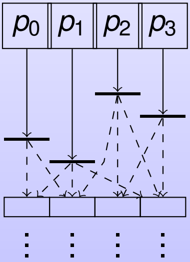

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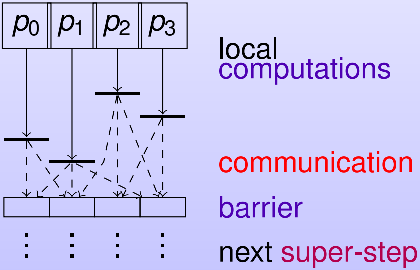

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BSML

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

Main idea

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- $\langle v_0, \ldots, v_{p-1} \rangle : \alpha$ par $\equiv v_i$ on node i
- Four primitives ⇒ simple semantics

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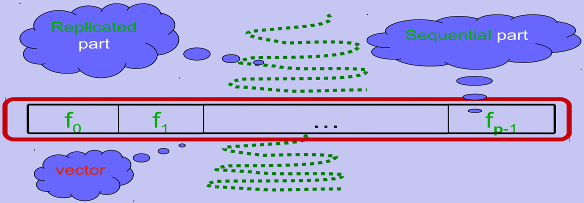
Parallel data structure ⇒ vectors:



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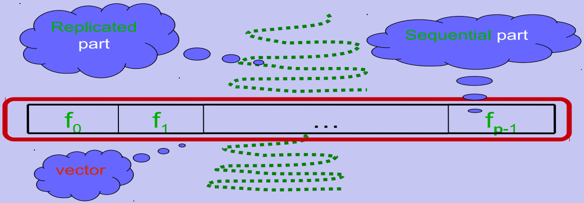

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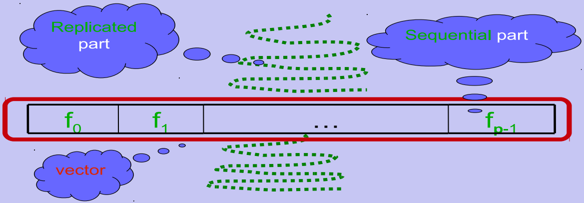

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- $\langle\langle \ldots \rangle\rangle$: local execution (vector)
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Implementation

Modular

- Based on a semantic study:
  BSML $\equiv$ **p**$\times$ ML + 2 BSP instructions (SPMD style)
- Different implementations: TCP/IP, MPI, PUB, $\cdots$

Extensions

Inspire:

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Example : BSP Sampling Sort

```
(* 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) ≫
```

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- "All" OCaml codes can be used
- Easy to get a BSML code from a BSP algorithm

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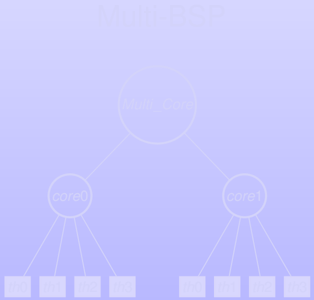
What is Multi-BSP? (Valiant)

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



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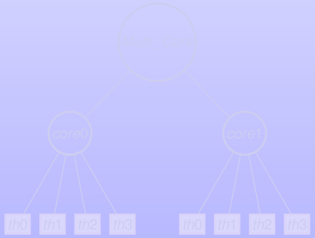

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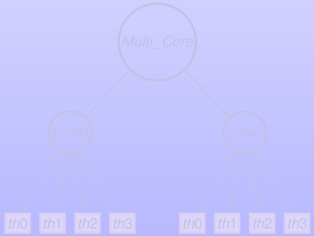

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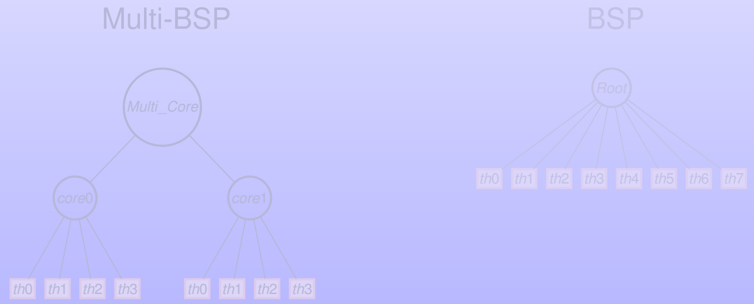

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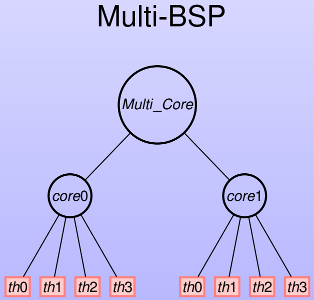

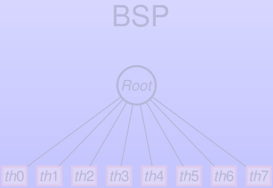

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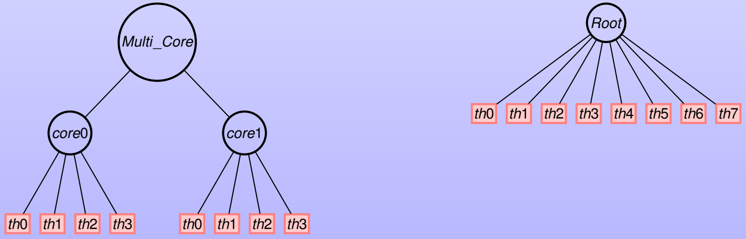

Multi-BSP Model (2)

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
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Example: 16 quad-chips with octo-cores

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

Multi-BSML Language (1)

Syntaxic construction

```
let multi f [args] =
 let cst = CodeOCaml
 where node [args] = CodeBSML ...
                     ≪ f args ≫
                   ... CodeBSML
 where leaf [args] = CodeOCaml
 in f ...
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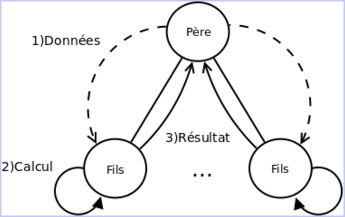

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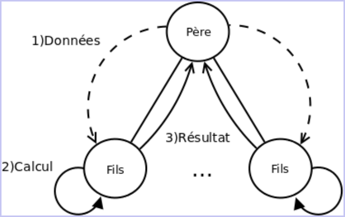

Limitations and differences

- Nodes are implicit computation units
- Horizontal communications between level components
- Garbage collector $\Rightarrow$ 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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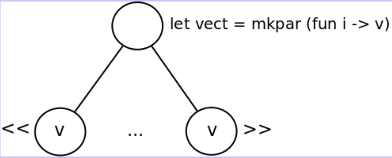
Copy memory values and distribution of values

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

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

  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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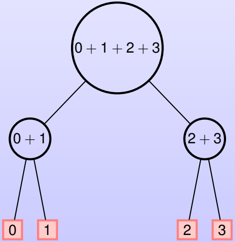
Extension

Two new keywords:

- finally; pushes up a value and keeps a value
- where default; keeps a value even if the recursive calls generates partial trees; Optional if the language allows to raise exceptions

Example

Keep the intermediate results of the sum




```
let multi sum_list l =

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

  where leaf l =
    let s = sumSeq l in
     finally ~up:s ~keep:s

  where default = 0 (* not used *)
```

Implementation

Sequential (currently test phase)

For debugging and toplevel

- tree structure of data
- A global tree of Hashtables to represent the memories

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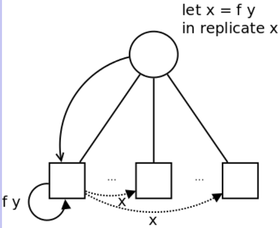

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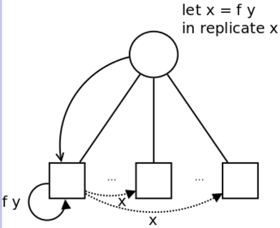

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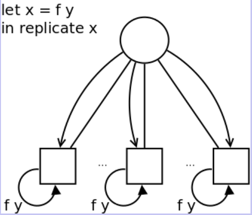

Skeleton (For Coq) Example

Why ?

Embed Multi in Coq:

- Syntax extensions not friendly in Coq
- **finally** too close to a monad (side effect)

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The multi skeleton

mktree : 'a tree → 'b → 'e tree → down → leaff → up → control → ('c∗'e tree)

where

down: 'a → 'b → 'b par

leaf: 'e → 'a → 'b → ('c ∗ 'e)

up: 'd par → 'e → 'a → 'b → ('c ∗ 'e)

control: 'c par→ 'e→ 'a→ 'b→ UP **of** ('d par ∗ 'e) | DOWN **of** ('b ∗ 'e)

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- BSP ⇒ BSML
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- Examples and benchmarks
- Type system for a subpart of OCaml again

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