Bulk Synchronous Parallel ML Modular Implementation and Performance Prediction

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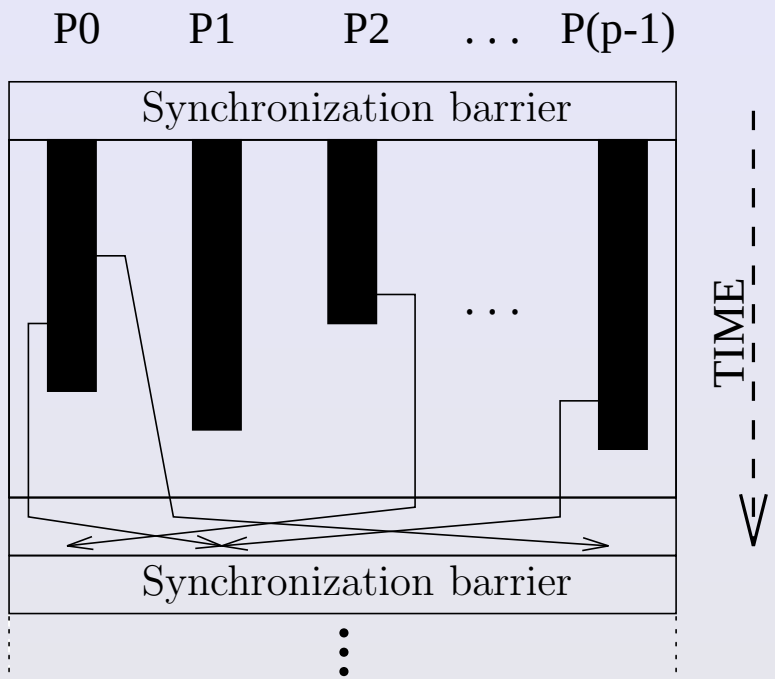
Introduction

- The design of a parallel language is a trade-off between :
  - expressivity
  - simple semantics & performance prediction
- Bulk Synchronous Parallel ML :
  - describes Bulk Synchronous Parallel algorithms (explicit processes & communications)
  - deadlock free & deterministic
  - pure functional semantics (based on a confluent extension of the λ-calculus)

Bulk Synchronous Parallelism



$$T(s) = \max_{0 \leq i < p} w_i + h \times g + L$$

Overview

- Functional language (ML family) + BSP operations
- BSML prog. = usual ML prog. + operations on parallel vectors
- Parallel vector : α par (size p)
- Access to BSP parameters :

bsp_p: unit $\rightarrow$ int
bsp_g: unit $\rightarrow$ float
bsp_l: unit $\rightarrow$ float

Creation of parallel vectors

$$\text{mkpar} : (\text{int} \rightarrow \alpha) \rightarrow \alpha \text{ par}$$

$$(\text{mkpar } f)$$

$(f\ 0)$	$(f\ 1)$	$\cdots$	$(f\ (p-1))$

$$\text{BSP cost} : \max_{0 \leq i < p} w_i$$

Point-wise parallel application

$$\text{apply} : (\ \alpha \rightarrow \beta\ )\ \text{par} \rightarrow \alpha\ \text{par} \rightarrow \beta\ \text{par}$$

$$\left(\text{apply} \begin{array}{|c|c|c|c|} \hline f_0 & f_1 & \cdots & f_{p-1} \\ \hline \end{array}\right.$$

$$\left. \begin{array}{|c|c|c|c|} \hline v_0 & v_1 & \cdots & v_{p-1} \\ \hline \end{array}\right)$$

$$= \begin{array}{|c|c|c|c|} \hline (f_0\ \ v_0) & (f_1\ \ v_1) & \cdots & (f_{p-1}\ \ v_{p-1}) \\ \hline \end{array}$$

$$\text{BSP cost} : \max_{0 \leq i < p} w_i$$

Communication

type α option = None | Some of α

put: (int $\rightarrow$ α option) par $\rightarrow$ (int $\rightarrow$ α option) par

$$\left(\text{put} \quad \boxed{f_0} \boxed{f_1} \boxed{\cdots} \boxed{f_{p-1}}\right) = \boxed{g_0} \boxed{g_1} \boxed{\cdots} \boxed{g_{p-1}}$$

0	1	2	3
None	(f_1 0)	(f_2 0)	(f_3 0)
None	(f_1 1)	(f_2 1)	(f_3 1)
None	(f_1 2)	(f_2 2)	(f_3 2)
Some v	(f_1 3)	(f_2 3)	(f_3 3)

$\Rightarrow$

0	1	2	3
None	None	None	Some v
(g_0 1)	(g_1 1)	(g_2 1)	(g_3 1)
(g_0 2)	(g_1 2)	(g_2 2)	(g_3 2)
(g_0 3)	(g_1 3)	(g_2 3)	(g_3 3)

BSP cost : $\max_{0 \leq i < p} w_i + h \times g + L$

Projection

$$\text{proj}: \ \alpha \text{ option par} \rightarrow (\text{int} \rightarrow \ \alpha \text{ option})$$

$$\left(\text{proj} \quad \boxed{v_0 \mid v_1 \mid \cdots \mid v_{p-1}}\right) = \begin{array}{lll} \text{function} & 0 & \rightarrow \ v_0 \\ \mid & 1 & \rightarrow \ v_1 \\ & \vdots & \\ \mid & p-1 & \rightarrow \ v_{p-1} \end{array}$$

$$\text{BSP cost} : \max_{0 \leq i < p} w_i + h \times g + L$$

Examples (1)

```
let noSome (Some x) = x

let procs () = [0;1;2;...;bsp_p()−1] (* Pseudo code *)

let replicate x = mkpar(fun pid→ x)

let parfun f vec = apply (replicate f) vec

let parfun2 f vec1 vec2 = apply (parfun f vec1) vec2

let _ =
  let print = fun i n → Printf.printf "Processor␣%d␣of␣%d\n" i n in
  parfun2 print (mkpar(fun pid→ pid)) (replicate (bsp_p()))
```

Examples (2)

```
(* totex: α par → (int → α ) par *)
let totex vv = parfun (compose noSome)
  (put(parfun (fun v dst→ Some v) vv))

(* total_exchange: α par → α list par *)
let total_exchange vec =
  parfun2 List.map (totex vec) (replicate (procs()))

(* fold_direct: ( α → α → α ) → α par → α par *)
let fold_direct op vec =
  let local_reduce = function h::t→ List.fold_left op h t in
  parfun local_reduce (total_exchange vec)
```

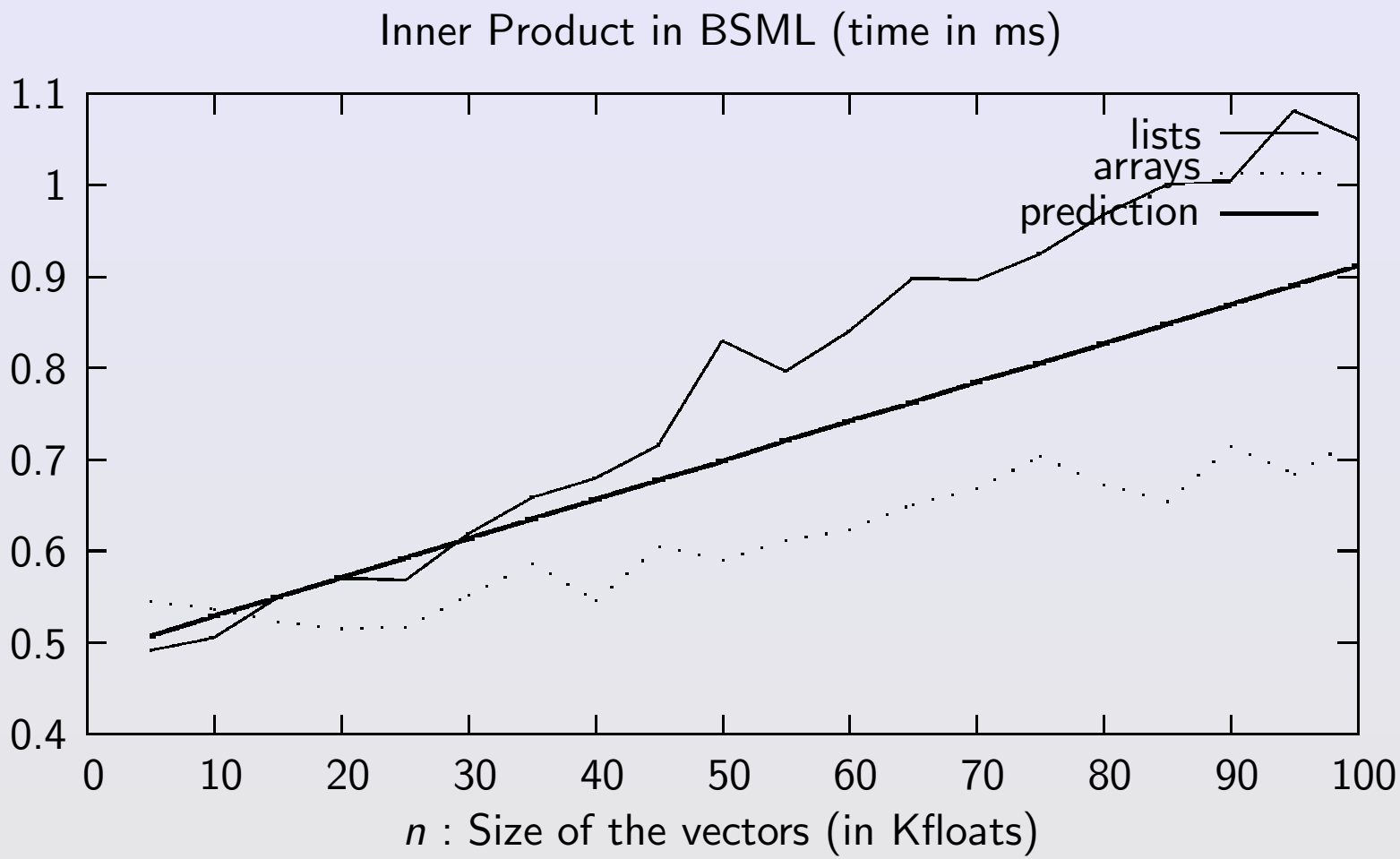
Examples (3)

```
let inprod_array v1 v2 = let s = ref 0. in
    for i = 0 to (Array.length v1)-1 do
        s:=!s+.(v1.(i)*.v2.(i));
    done; !s

let inprod_list v1 v2 =
    List.fold_left2 (fun s x y-> s+.x*.y) 0. v1 v2

let inprod seqinprod v1 v2 =
  let local_inprod = parfun2 seqinprod v1 v2 in
  fold_direct (+.) local_inprod
```

Examples (4)


Inner Product in BSML (time in ms)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0
10
20
30
40
50
60
70
80
90
100
lists
arrays
prediction
n : Size of the vectors (in Kfloats)

Overview

- Two parts :
  - Primitives
  - Standard library
- Modular implementation :
  - The module of primitives is a functor
  - Low-level communication module (MPI, PUB, TCP/IP, SEQ)
  - Module for input/output (PAR, SEQ)
  - Module for parallel composition (Generic)

Conclusions and Future Work

- Bulk Synchronous Parallel ML is :
  - Simple
  - Efficient
  - Predictable
  - Partially certified
- Current implementation : 0.25 (MPI)
- Next release : 0.5 (end of July)

`http://bsmllib.free.fr`

Other Languages

- Minimally Synchronous Parallel ML
  - (Almost) same set of primitives
  - Different distribution execution : without globlal synchronization barrier
- Deparmental Metacomputing ML
  - Metacomputer : set of clusters
  - Each cluster programmed with BSML
  - Coordination with MSPML-like primitives