Parallel Functional Programming with Interaction Nets

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Fun in the REPL, Bristol
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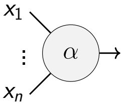
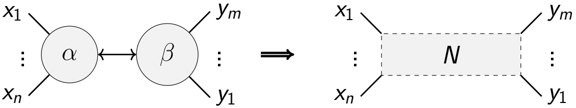
What are interaction nets?

Graph rewriting system (Lafont 1990).
"A new kind of programming language"

Finite set of *user-defined* agents:



Finite set of *user-defined* rewrite rules:



Maximum one rule per agent pair.

Set of auxiliary ports preserved.

Properties as programming language

- Turing complete
- Pattern matching
- Constant time rewrite operations
- Visual debugging

- Local reductions
- Diamond property

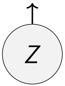
$$\begin{tikzcd} & N \arrow[dl] \arrow[dr] & \\ N1 \arrow[dr] & & N2 \arrow[dl] \\ & N' & \end{tikzcd}$$

- Explicit mandatory memory management

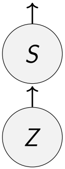
$\longrightarrow$ **Natural parallel execution**

Example constructor - Unary numbers

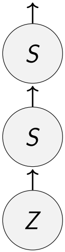
Zero



One



Two

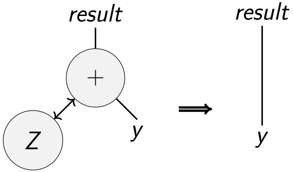


etc . . .

Example function - Unary number addition

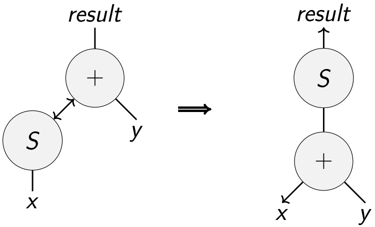
```
Z + y = y
```

```
add Z y = y
```



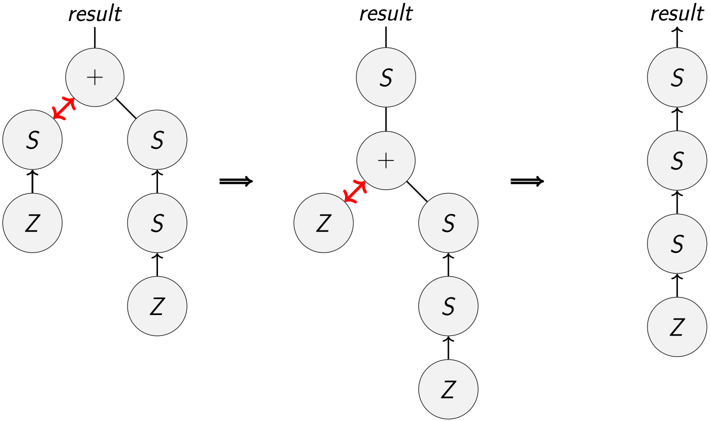
```
(S x) + y = S (x + y)
```

```
add (S x) y = S (add x y)
```

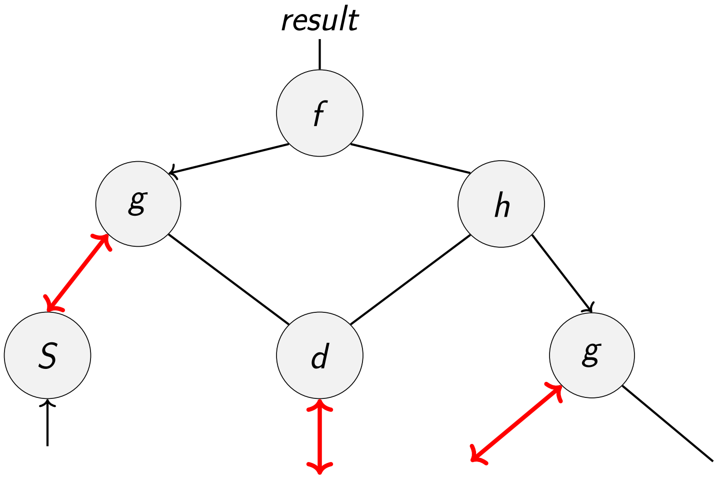


Example function - Unary number addition

$1 + 2 = 3$

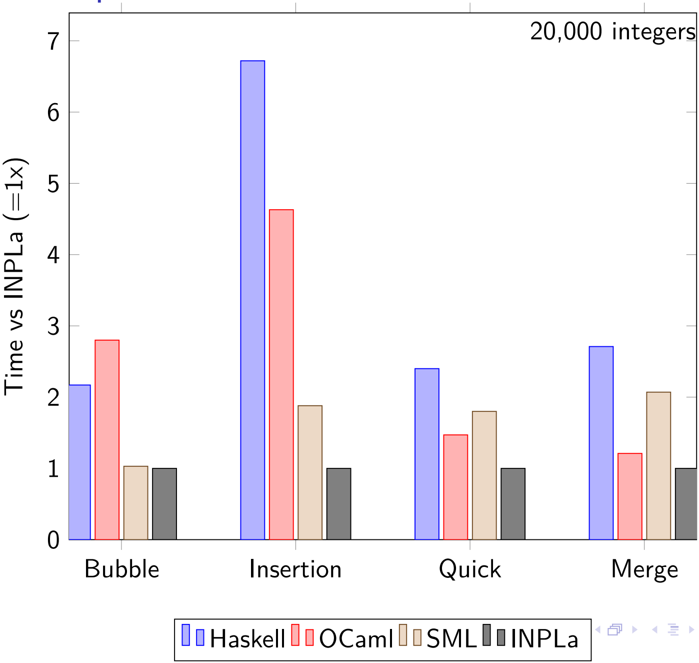


Parallel evaluation

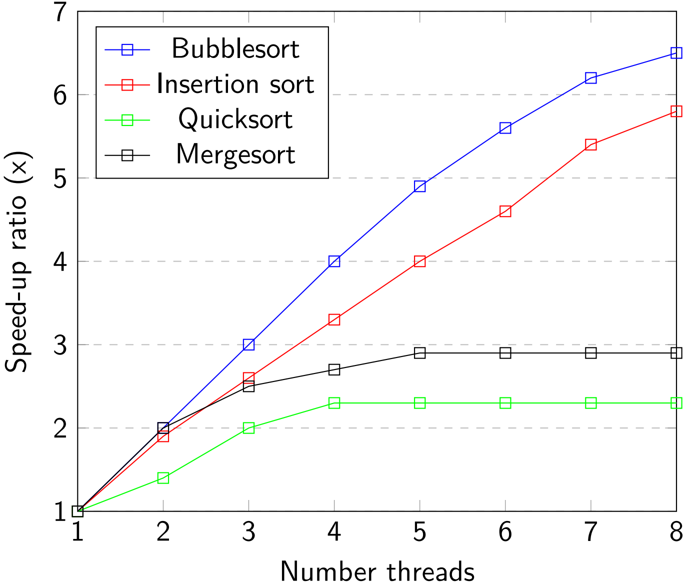


Sequential algorithm ≡ parallel algorithm.

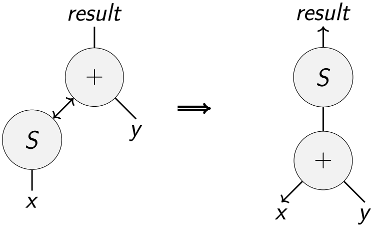
Impact of parallelism - benchmark results



Impact of parallelism - benchmark results



Towards a programming language

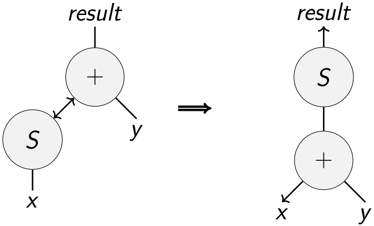


Flatten net[1]:

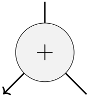
```
add(result,y)><S(x) => result~S(aux), add(aux,y)~x
```

[1] Sato, 2014 ; https://github.com/inpla/inpla

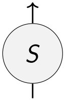
Towards a programming language



Agents whose principal port acts as input → *functions*.

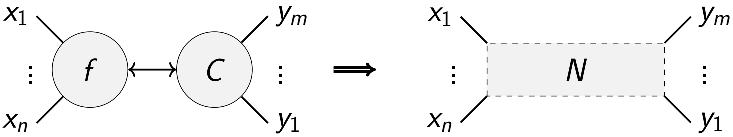


Agents whose principal port acts as output → *constructors*.



FLIN - a Functional Language for Interaction Nets

If f is a function and C is a constructor:



then:

$\texttt{f (C } \vec{y}\texttt{) } \vec{x}' \texttt{ = } N \ \vec{x}' \ \vec{y}$

where:

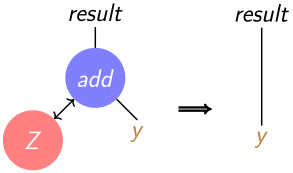
$\texttt{N = f ...| C ...| } \vec{y} \texttt{ | ...}$

and

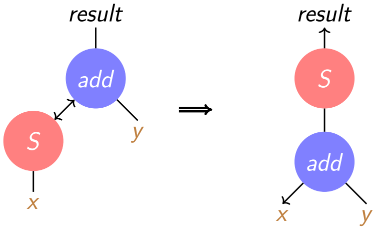
$\vec{x}' = \vec{x}$ adjusted for output.

FLIN ≅ Interaction Nets

```
add Z y = y
```

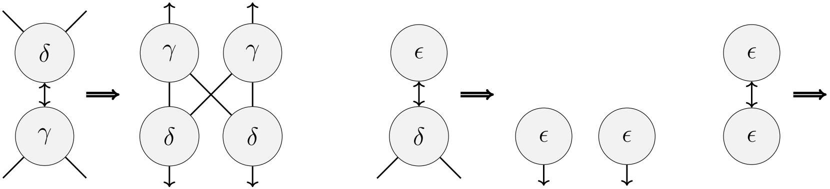


```
add (S x) y = S (add x y)
```



But not all interaction rules are functions!

Interaction combinators (Lafont 1997)



δ has two outputs.

ϵ consumes its input!

None are function-constructor systems!!

FLIN syntax for non-functions

Multiple outputs:

```
delta Z = Z,Z
delta (S x) = let x1,x2 = delta x in (S x1),(S x2)
```

No output or not function-constructor:

```
{eps><delta(a1,a2) => eps~a1, eps~a2}
{eps><eps => }
```

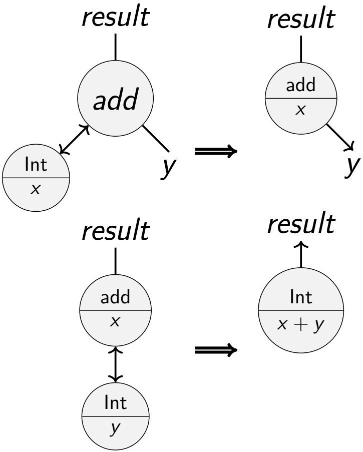
Or rewrite the algorithm!

FLIN examples

```
add Z y     = y
add (S x) y = S(add x y)

mult Z y     = Z {erase~y}
mult (S x) y = let y1,y2=dup x in add y1 (mult x y2)

fib Z     = Z
fib (S x) = fibS x
fibS Z     = S Z
fibS (S x) = let x1,x2=dup x in
                 add (fibS x1) (fib x2)

append [] ys     = ys
append (x:xs) ys = x:(append xs ys)
```

Extension - Attributes

Hold values within agents - ints, bools, strings etc & tuples of. (Fernández, Mackie, Pinto 2001)



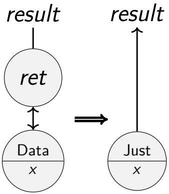
cf. λ-calculus → PCF.

Monads

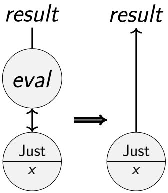
Translate: `bind m f` → `f (eval m)`

e.g. Maybe monad (following Jiresch 2010)

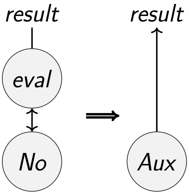
```
return Data.x = Just.x
```

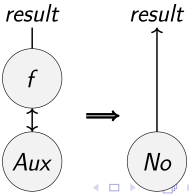


```
eval (Just x) = Just x
```



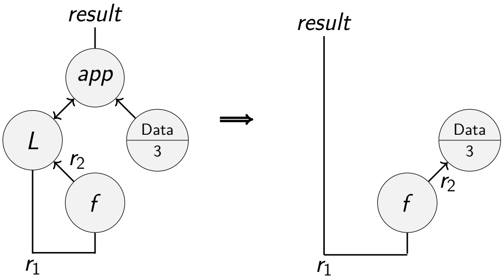
```
eval Nothing = Aux ; f Aux = Nothing
```





Higher order functions

"Package up" function in a constructor (λ-abstraction):

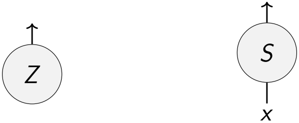


Rule: `app (L r2 r1) a = let r2=a in r1`

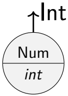
Application: `{app(result,a)><L(r2,r1), f(r1)~r2, a~Data(3)}`

Type system

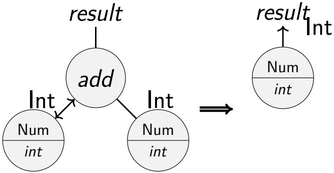
```
data Nat = Z | S Nat
```



```
type i::int => Num.i:Int
```



```
add ::  Int -> Int -> Int
```



Conclusions

- Interaction nets provide inherently parallel evaluation.
- INPLa implementation has encouraging benchmarks.
- FLIN - a simple function-constructor language maps 1:1 to interaction nets.
- FLIN can encode standard functional programming structures.
- FLIN programs run sequentially or in parallel based on resources.
- We have implemented a FLIN → INPLa transpiler.
- Language can be used directly for programming or as an intermediate language for a more complete language.