From Functional Programs to Pipelined Dataflow Networks

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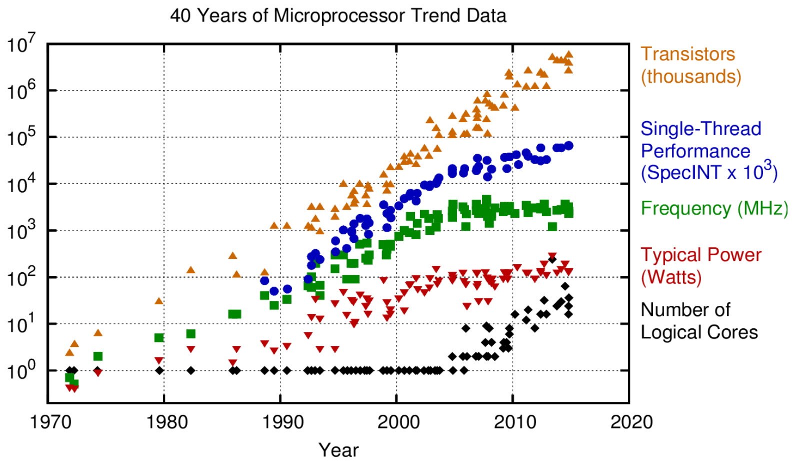
Martha A. Kim   Stephen A. Edwards

Columbia University

IBM PL Day, December 5, 2016

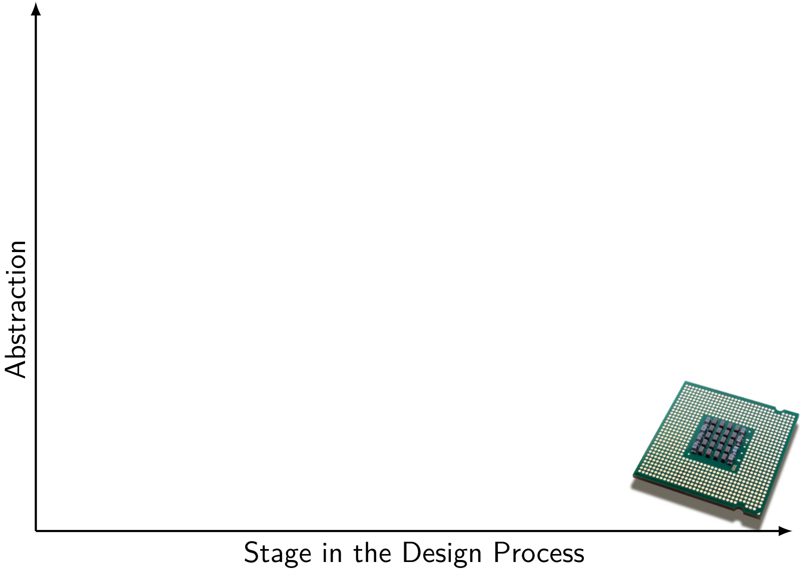
The Future of Hardware



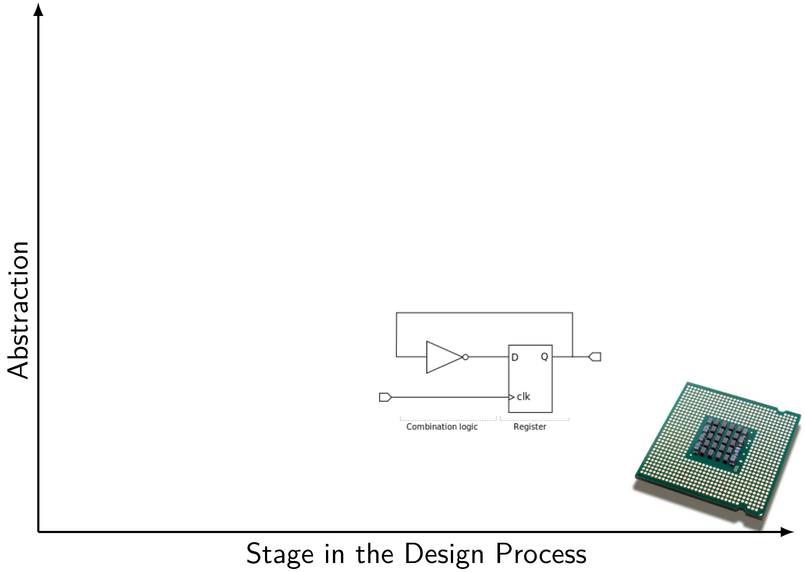
Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2015 by K. Rupp

Rupp, Karl. 40 Years Of Microprocessor Trend Data. 2015. Web. 28 Nov. 2016.

Designing Specialized Hardware



Designing Specialized Hardware



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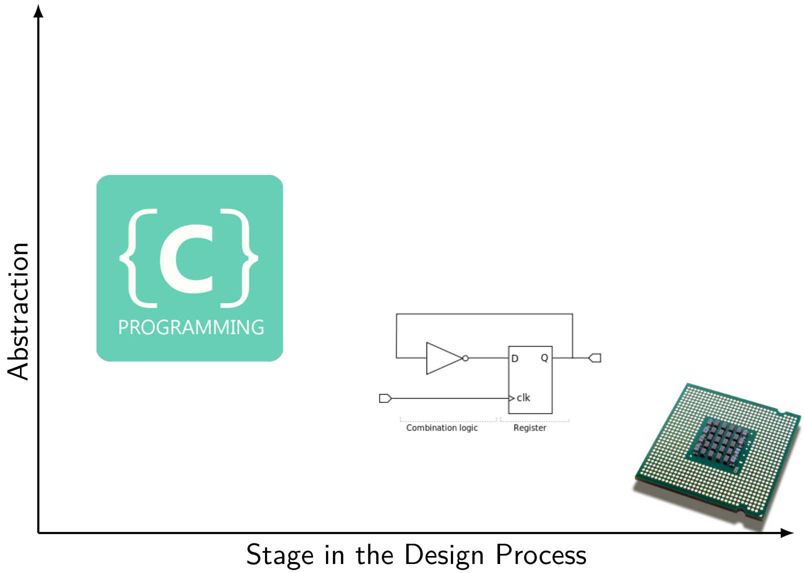

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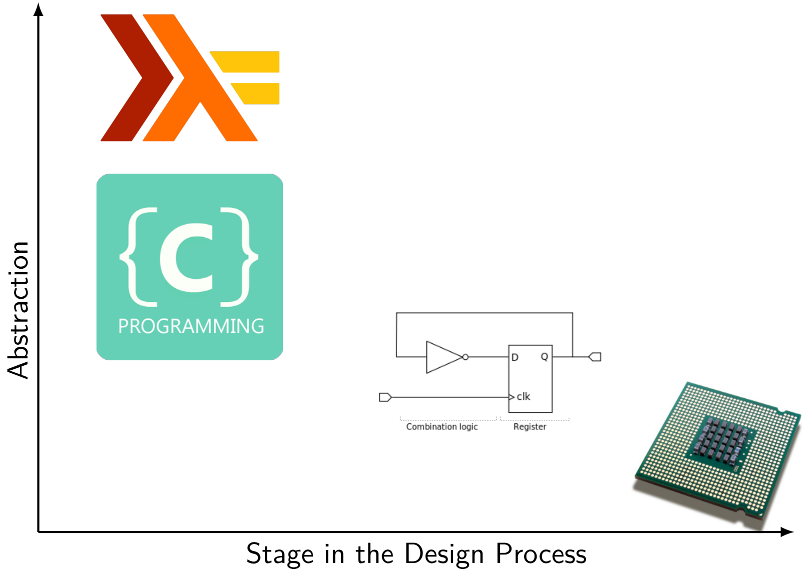

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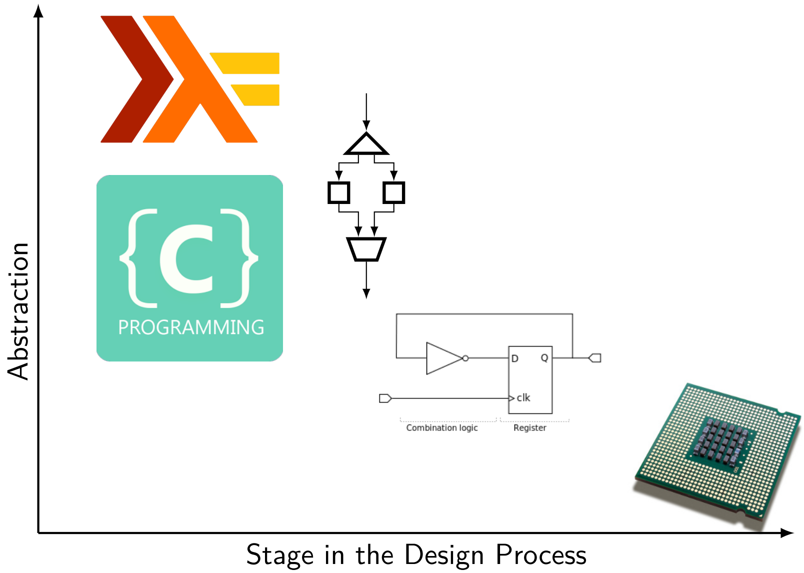
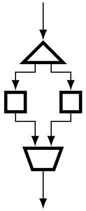


Overview



Floh IR

Dataflow Networks

Hardware Simulation

McGreggor, Duncan. Prefix Operators in Haskell. 2014. Web. 30 Nov. 2016.
Kuper, Jan. CλaSH: From Haskell to Hardware. 2015. Web. 30 Nov. 2016.

Floh (Functional Language on Hardware)

```
data List = Nil | Cons Int List




recMath :: List → Int → Int
recMath l x =
  case l of
    Nil         → add x 1
    Cons y xs → recMath xs (mul x y)
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- True recursion → stack

Floh (Functional Language on Hardware)

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data List = Nil Go | Cons Int List
data Go   = Go


recMath :: List → Int → Go → Int
recMath l x g =
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- True recursion → stack
- Trigger constants with **Go**

Floh (Functional Language on Hardware)

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data List   = Nil Go | Cons Int ListPtr
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- True recursion → stack
- Trigger constants with **Go**
- Recursive types → explicit memory operations

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Strictness Policies

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Strictness Policies

- Data Constructors: **strict** – evaluate *all* arguments

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- True recursion → stack
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Strictness Policies

- Data Constructors: **strict** – evaluate *all* arguments
- Functions: **non-strict** – evaluate *first* argument

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- True recursion → stack
- Trigger constants with **Go**
- Recursive types → explicit memory operations

Strictness Policies

- Data Constructors: **strict** – evaluate *all* arguments
- Functions: **non-strict** – evaluate *first* argument
- Enables pipeline parallelism!

From Floh to Dataflow

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recMath lp x g =
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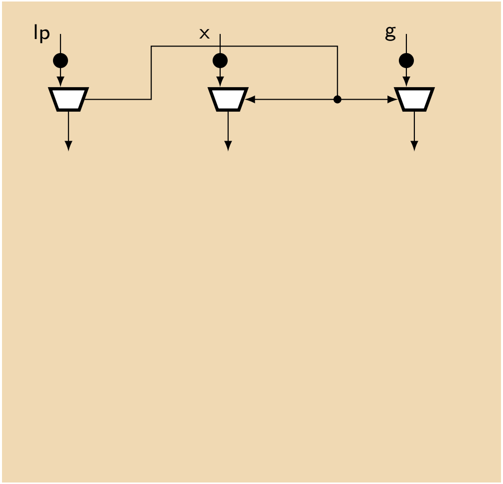

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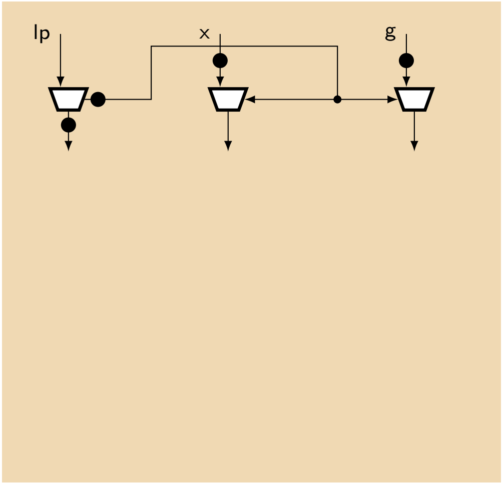

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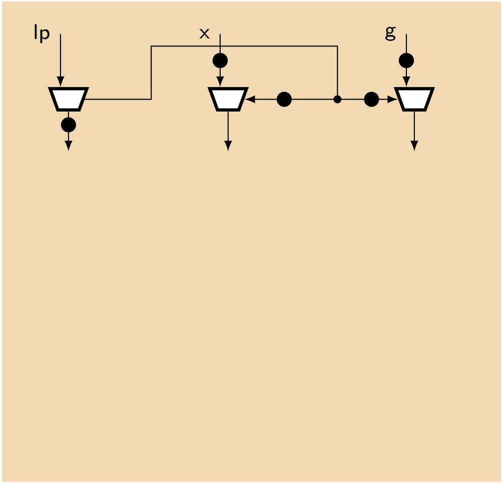

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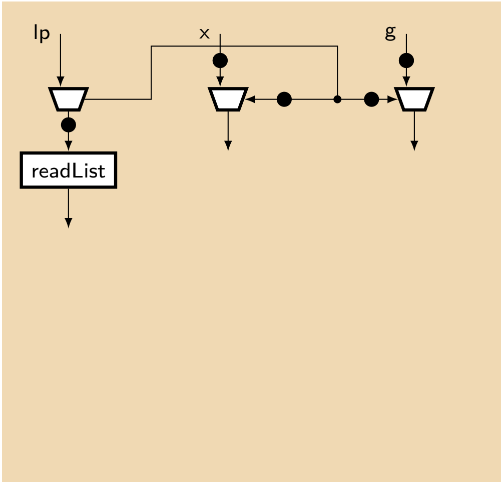

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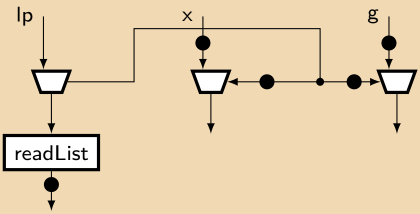

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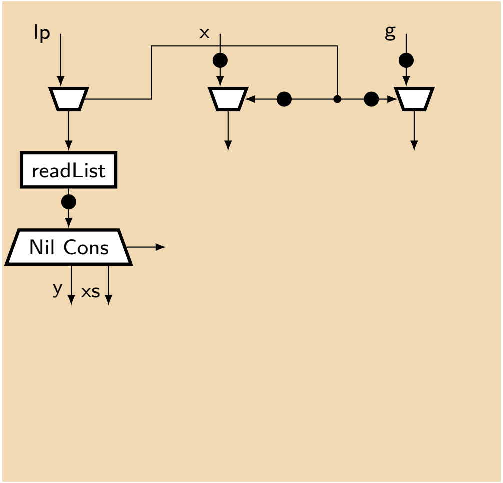

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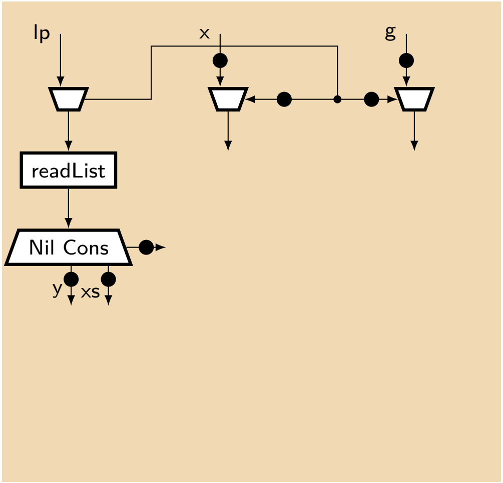

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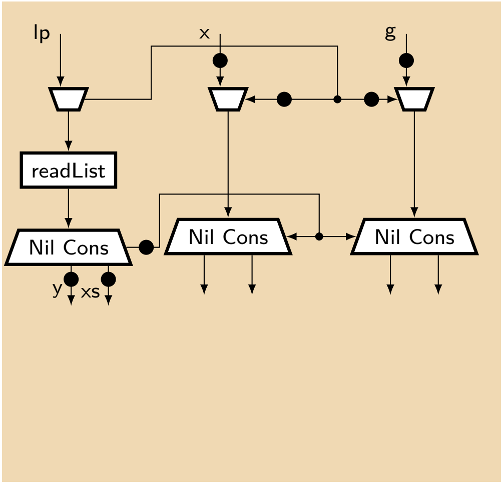

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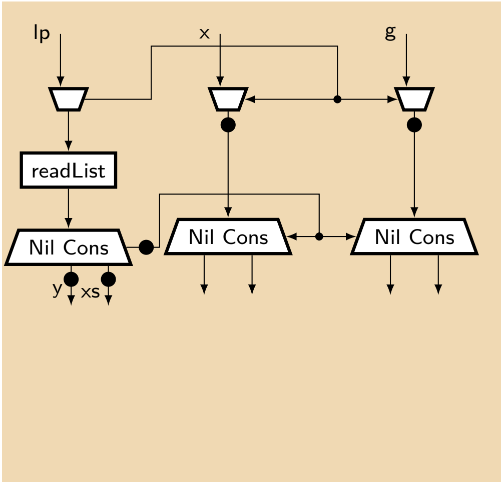

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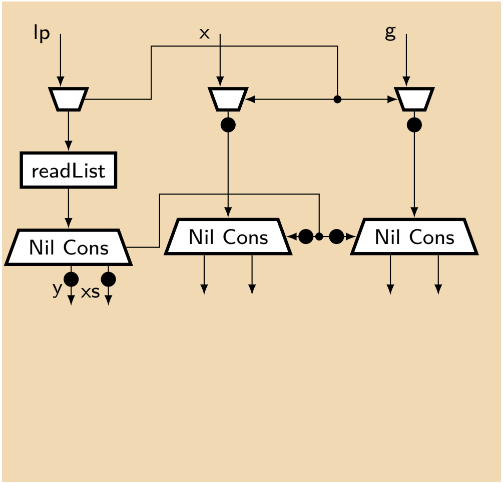

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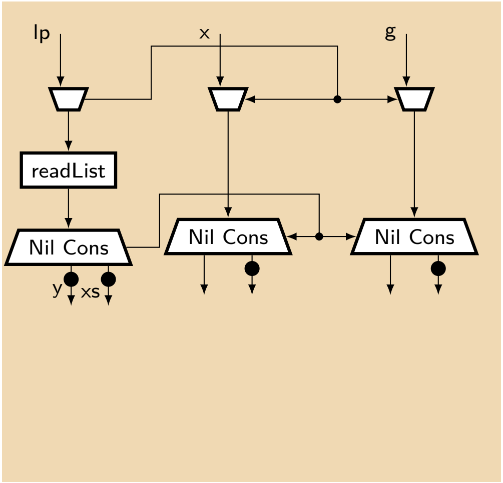

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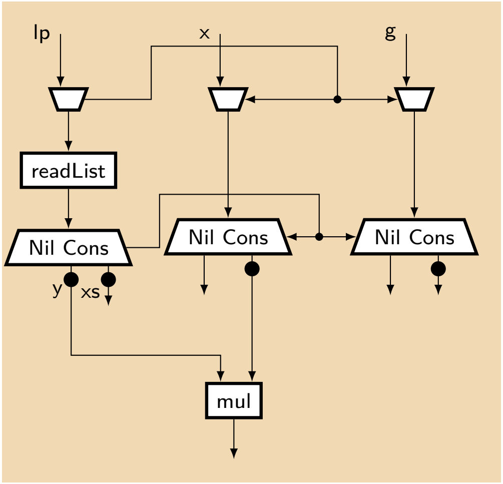

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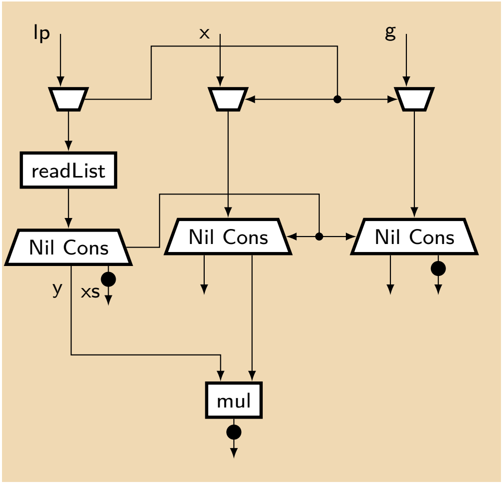

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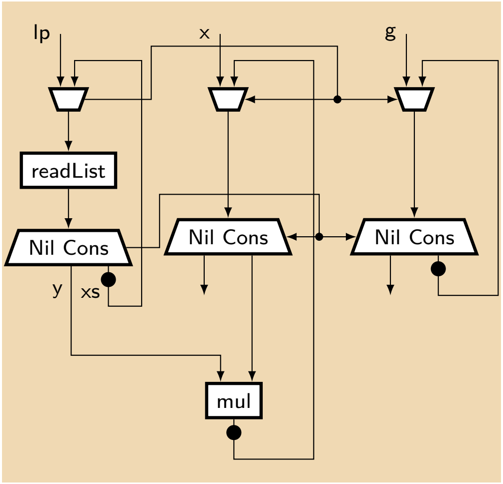

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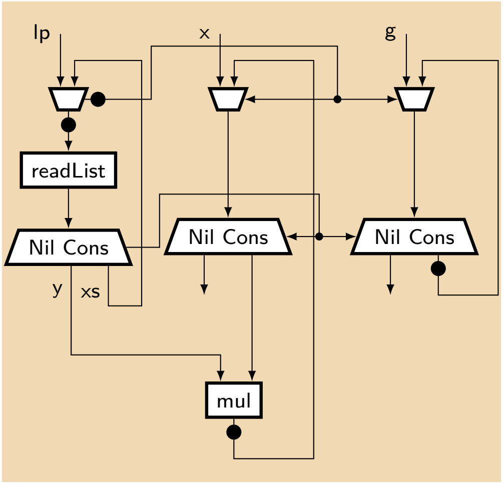

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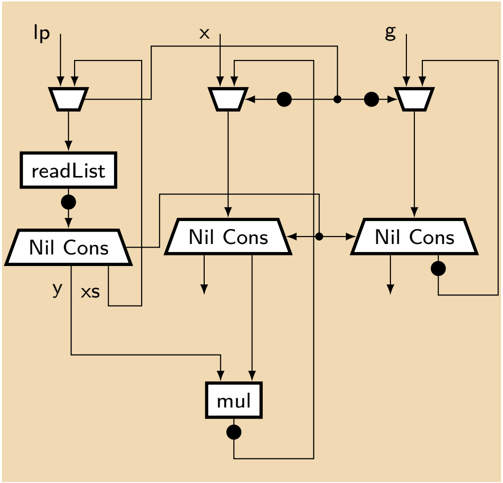

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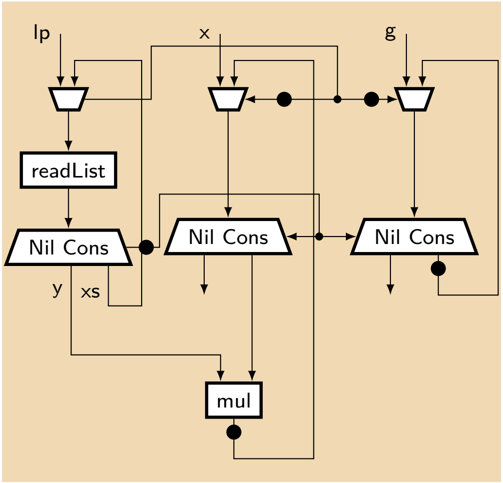

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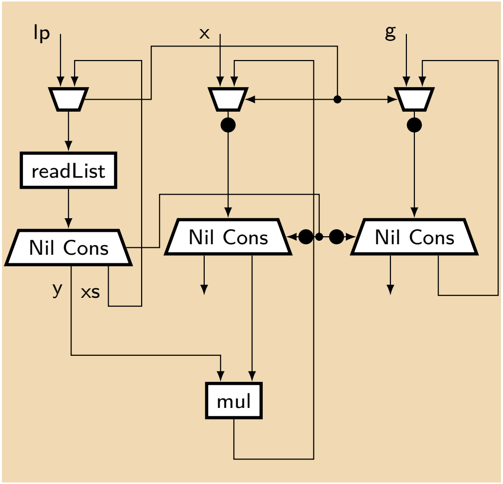

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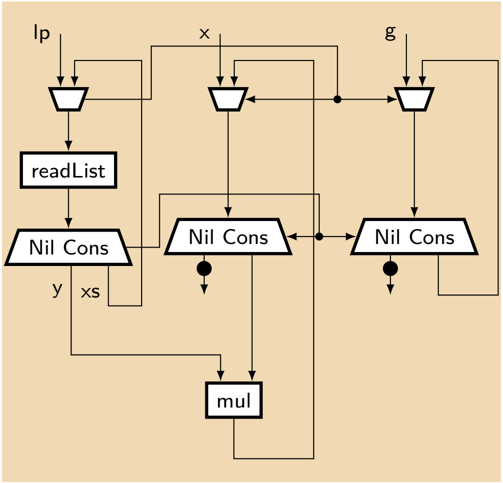

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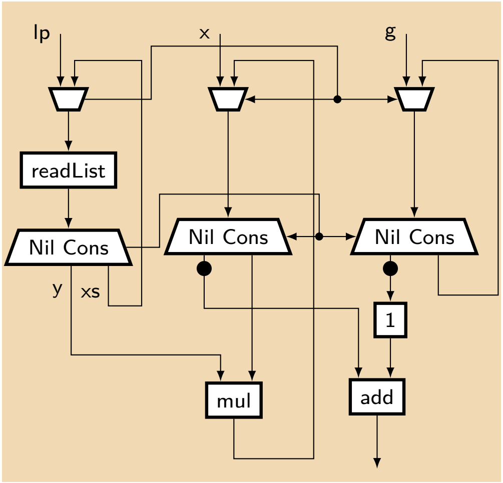

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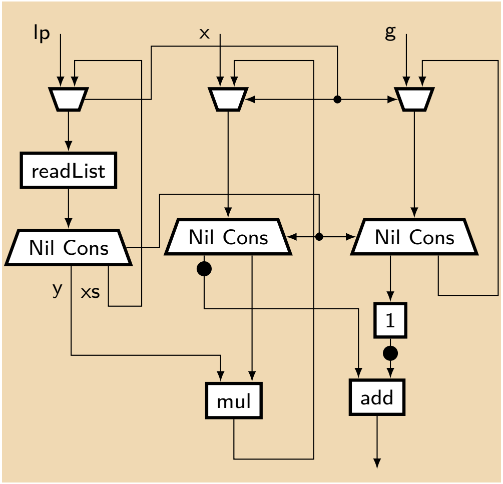

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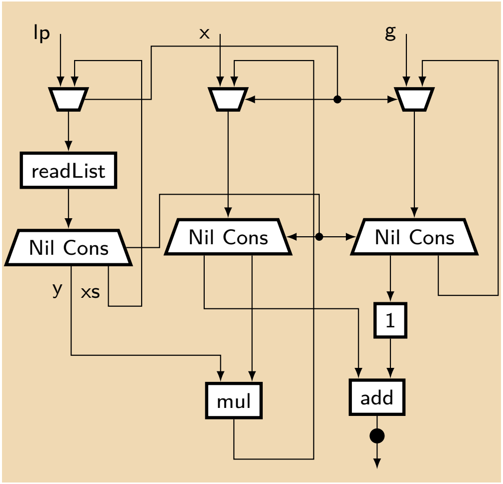
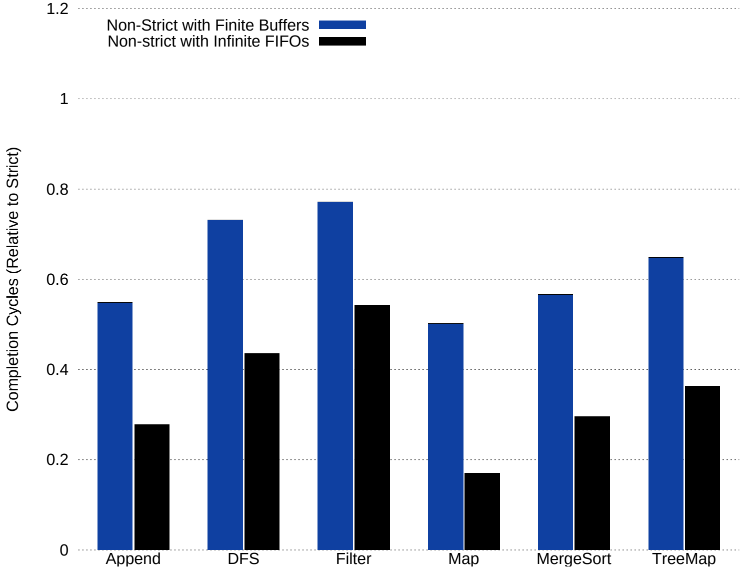


Non-strictness Exploits Pipeline Parallelism



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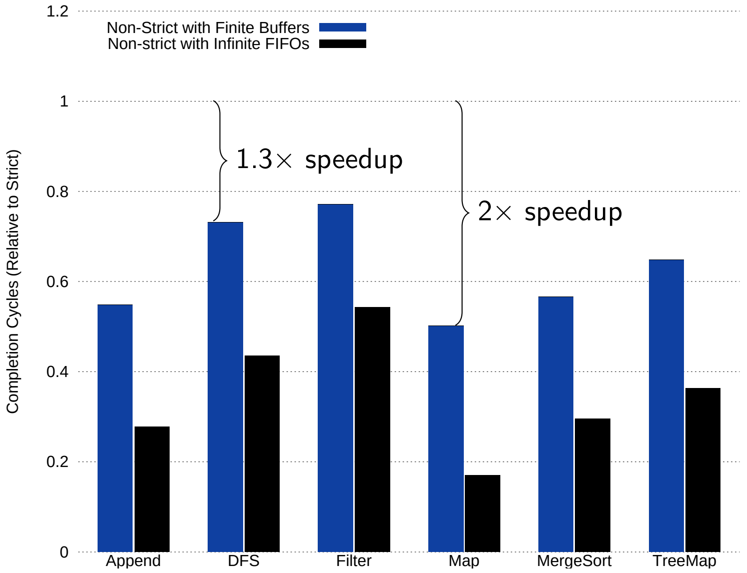

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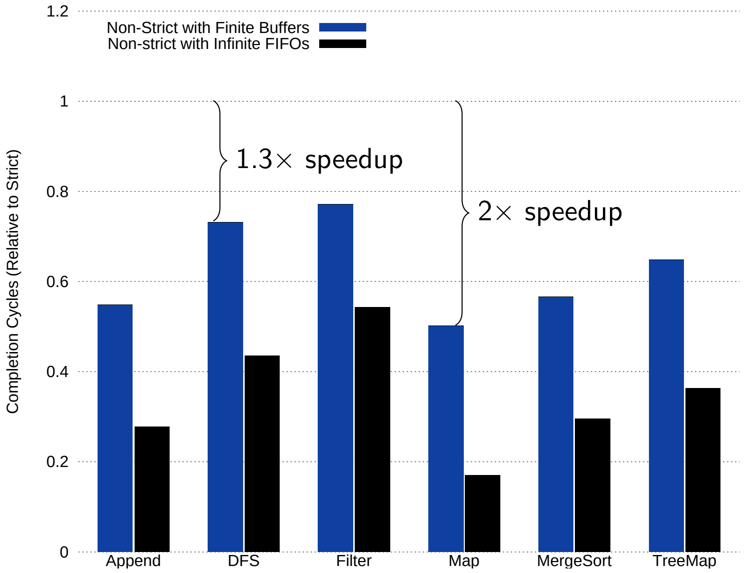
Non-Strict with Finite Buffers
Non-strict with Infinite FIFOs
Completion Cycles (Relative to Strict)
1.3× speedup
2× speedup
Append
DFS
Filter
Map
MergeSort
TreeMap