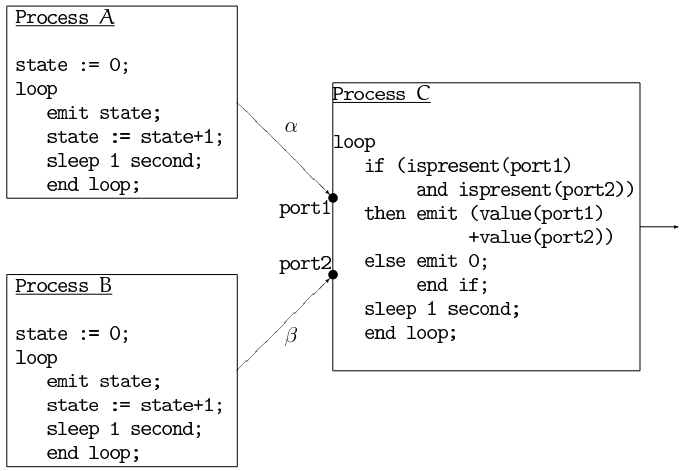
System Modeling

Introduction
Rugby Meta-Model
Finite State Machines
Petri Nets
Untimed Model of Computation
Synchronous Model of Computation
Timed Model of Computation
Integration of Computational Models
Tightly Coupled Process Networks

Non-blocking Read

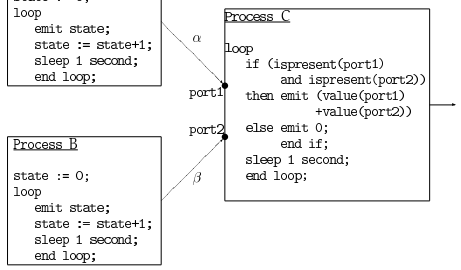


Tightly Coupled Networks

Common assumptions for untimed, synchronous and timed MoC:

- An input channel cannot be probed for the presence of data. The read operation is called a **blocking read**.
- The communication channels are **unbounded FIFO buffers**. The writing to and reading from a channel are entirely decoupled.
- The process network is **determinate** if all processes are determinate, i.e. the connecting network does not introduce nondeterminism.

Non-blocking Read - cont'd



delay(α)=0
delay(β)=0

Process ports	Output sequence				
A output	0	1	2	3	4
B output	0	1	2	3	4
C input 1	0	1	2	3	4
C input 2	0	1	2	3	4
C output	0	2	4	6	8

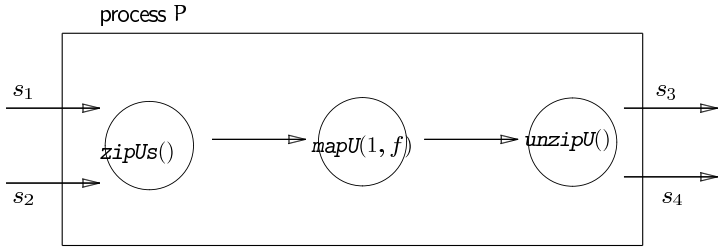
delay(α)=0
delay(β)=1

A output	0	1	2	3	4
B output	0	1	2	3	4
C input 1	0	1	2	3	4
C input 2	-	0	1	2	3
C output	0	1	3	5	7

Nondeterministic Channel Delays

- No nondeterminism of functionality if
  - ⋆ Time is not explicit, and absence of events cannot be sensed,
  - ⋆ or time is explicitly part of the functionality.
- Deterministic behavior can be realized in a nondeterministic MoC by implementing a blocking read.

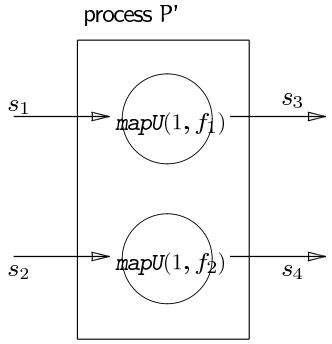
Control Coupling of Independent Data Streams - 1



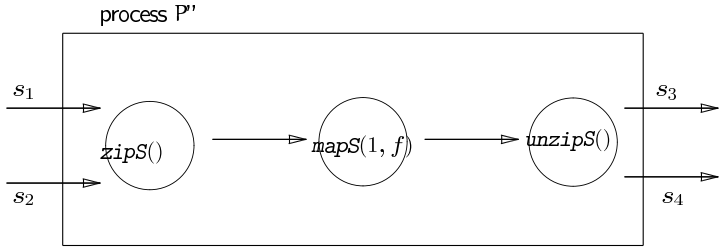
$$f((x,y) = (f_1(x), f_2(y))$$

Stream $s_1 - s_3$ is independent of $s_2 - s_4$.

Control Coupling of Independent Data Streams - 2



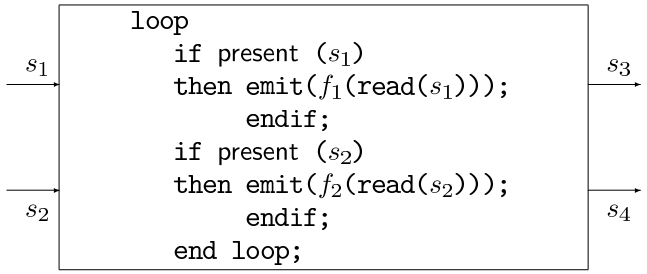
Control Coupling of Independent Data Streams - 3



$$\begin{aligned} f(\perp) &= \perp \\ f(\perp, y) &= (\perp, f_2(y)) \\ f(x, \perp) &= (f_1(x), \perp) \\ f(x, y) &= (f_1(x), f_2(y)) \end{aligned}$$

Control Coupling of Independent Data Streams - 4

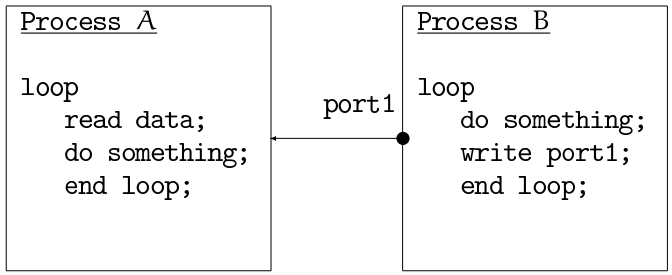
process Q



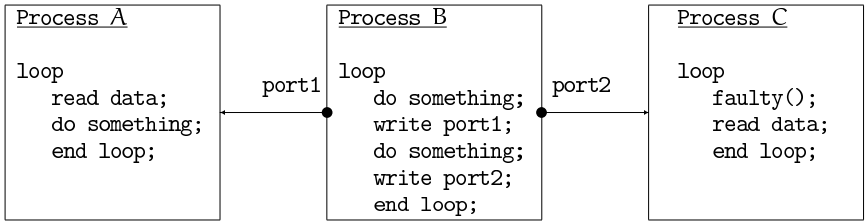
A process with non-blocking read implemented by function present.

Rule: **If s_o does not depend on s_i then the reading of, processing of and waiting for s_i data must not change or block the generation of s_o data.**

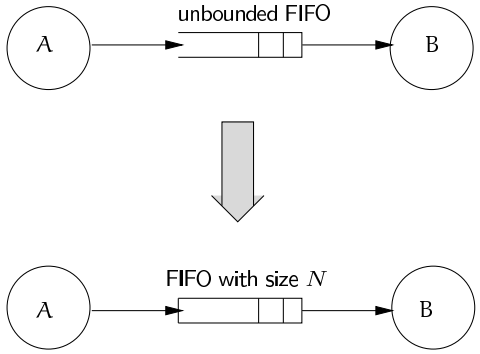
Blocking Read and Blocking Write - 1



Blocking Read and Blocking Write - 2



Oversynchronization
FIFO Refinement



Under which condition does the refined system behave identical to the original?

Identity Condition

ev-time(p) ... evaluation instances of p.
emitted(p, i) ... number opf tokens emitted in cycle i.
consumed(p, i) ... number opf tokens consumed in cycle i.

$$E_{p,t} = \sum_{j=0}^{J} \text{emitted}(p, j) \qquad \text{where} \qquad J = \max(k : t_k \leq t)$$

$$C_{p,t} = \sum_{j=0}^{J} \text{consumed}(p, j) \qquad \text{ev-time}(p) = \langle t_0, t_1, t_2, \ldots \rangle$$

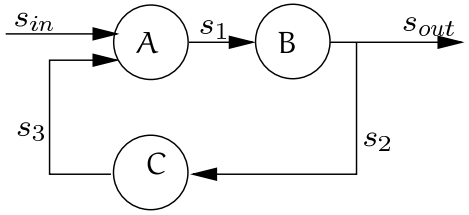
Process A will never be blocked due to a full FIFO of size N if

$$E_{\mathrm{A},t} \geq C_{\mathrm{B},t} \geq E_{\mathrm{A},t} - N \qquad \textbf{for all } t \in \textbf{ev-time}(\mathrm{A})$$

Effects of Blocking Finite FIFOs

- No feedback loops:
  - ⋆ All system output signals are eventually the same as in the specification.
  - ⋆ Output events may be delayed.
  - ⋆ The shorter the FIFOs the longer the delay may be.
- With feedback loops:
  - ⋆ The generated output events are identical up to the length of the generated signals.
  - ⋆ The output signals may be strict prefixes of the corresponding specification output signals.

Finite FIFOs (size 1) with Feedback Loops



$\mathrm{A} = \texttt{zipUs}(1, 1)$

$\mathrm{B} = \texttt{mealyU}(1, f, g, 0)$

where $g(0, (x_1, x_2)) = 1$

$g(1, (x_1, x_2)) = 2$

$g(n, (x_1, x_2)) = 2$ for $n > 2$

$f(0, (x_1, x_2)) = \langle x_1, x_1, x_2 \rangle$

$f(1, (x_1, x_2)) = \langle x_1, x_2 \rangle$

$f(2, (x_1, x_2)) = \langle x_1 \rangle$

$\mathrm{C} = \texttt{initU}(\langle x_0 \rangle)$

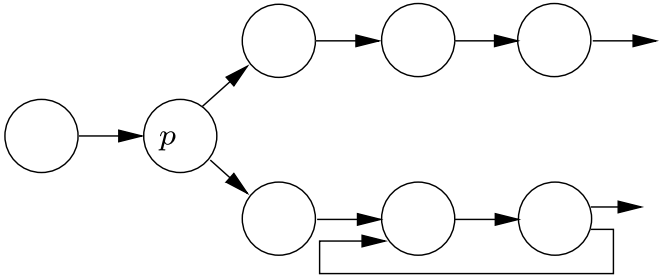
Infinite FIFOs with Feedback Loop

Step	Process	s_{in}	s_1	s_2	s_3	s_{out}
-	-	$\langle x_1, x_2, x_3 \rangle$	$\langle\rangle$	$\langle\rangle$	$\langle\rangle$	$\langle\rangle$
1	C	$\langle x_1, x_2, x_3 \rangle$	$\langle\rangle$	$\langle\rangle$	$\langle x_0 \rangle$	$\langle\rangle$
2	A	$\langle x_2, x_3 \rangle$	$\langle (x_0, x_1) \rangle$	$\langle\rangle$	$\langle\rangle$	$\langle\rangle$
3	B	$\langle x_2, x_3 \rangle$	$\langle\rangle$	$\langle x_0, x_0, x_1 \rangle$	$\langle\rangle$	$\langle x_0, x_0, x_1 \rangle$
4	C	$\langle x_2, x_3 \rangle$	$\langle\rangle$	$\langle x_0, x_1 \rangle$	$\langle x_0 \rangle$	$\langle x_0, x_0, x_1 \rangle$
5	A	$\langle x_3 \rangle$	$\langle (x_0, x_2) \rangle$	$\langle x_0, x_1 \rangle$	$\langle\rangle$	$\langle x_0, x_0, x_1 \rangle$
6	B	$\langle x_3 \rangle$	$\langle\rangle$	$\langle x_0, x_1, x_0, x_2 \rangle$	$\langle\rangle$	$\langle x_0, x_0, x_1, x_0, x_2 \rangle$
7	C	$\langle x_3 \rangle$	$\langle\rangle$	$\langle x_1, x_0, x_2 \rangle$	$\langle x_0 \rangle$	$\langle x_0, x_0, x_1, x_0, x_2 \rangle$
8	A	$\langle\rangle$	$\langle (x_0, x_3) \rangle$	$\langle x_1, x_0, x_2 \rangle$	$\langle\rangle$	$\langle x_0, x_0, x_1, x_0, x_2 \rangle$
9	B	$\langle\rangle$	$\langle\rangle$	$\langle x_1, x_0, x_2, x_0 \rangle$	$\langle\rangle$	$\langle x_0, x_0, x_1, x_0, x_2, x_0 \rangle$
10	C	$\langle\rangle$	$\langle\rangle$	$\langle x_0, x_2, x_0 \rangle$	$\langle x_1 \rangle$	$\langle x_0, x_0, x_1, x_0, x_2, x_0 \rangle$

Finite FIFOs with Feedback Loop

Step	Process	s_{in}	s_1	s_2	s_3	s_{out}
-	-	$\langle x_1, x_2, x_3 \rangle$	$\langle\rangle$	$\langle\rangle$	$\langle\rangle$	$\langle\rangle$
1	C	$\langle x_1, x_2, x_3 \rangle$	$\langle\rangle$	$\langle\rangle$	$\langle x_0 \rangle$	$\langle\rangle$
2	A	$\langle x_2, x_3 \rangle$	$\langle (x_0, x_1) \rangle$	$\langle\rangle$	$\langle\rangle$	$\langle\rangle$
3	B blocked	$\langle x_2, x_3 \rangle$	$\langle\rangle$	$\langle x_0 \rangle$	$\langle\rangle$	$\langle x_0 \rangle$
4	C	$\langle x_2, x_3 \rangle$	$\langle\rangle$	$\langle\rangle$	$\langle x_0 \rangle$	$\langle x_0 \rangle$
5	B resumed; blocked	$\langle x_2, x_3 \rangle$	$\langle\rangle$	$\langle x_0 \rangle$	$\langle x_0 \rangle$	$\langle x_0, x_0 \rangle$
6	A	$\langle x_3 \rangle$	$\langle (x_0, x_2) \rangle$	$\langle x_0 \rangle$	$\langle\rangle$	$\langle x_0, x_0 \rangle$
7	C	$\langle x_3 \rangle$	$\langle (x_0, x_2) \rangle$	$\langle\rangle$	$\langle x_0 \rangle$	$\langle x_0, x_0 \rangle$
8	B resumed	$\langle x_3 \rangle$	$\langle (x_0, x_2) \rangle$	$\langle x_1 \rangle$	$\langle x_0 \rangle$	$\langle x_0, x_0, x_1 \rangle$
9	all blocked					

Oversynchronization



A deadlock in the lower branch can block exectution of the upper branch.

Summary

- Data dependencies determine the minimum coupling between processes.
- Control dependencies can, sometimes unnecessarily, increase the process coupling.
- Limited and shared resources may further increase process coupling.
- In deterministic process networks:
  - ⋆ without cyclic dependencies output events may only be delayed due to coupling;
  - ⋆ with cyclic dependencies dealock may occurr due to coupling.
- In nondeterministic process networks the resulting behaviour may be very different.