Choreographic Development of Message-Passing Applications

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In the next 90 minutes...

Prologue	An intuitive account
Act I	Some definitions
Act II	A tool
Act III	A little exercise
Epilogue	Work in progress

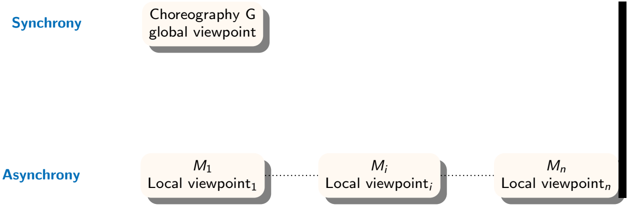
– Prologue –

[An intuitive account]

“Top-down”

Quoting W3C

“Using the Web Services Choreography specification, a contract containing a global definition of the common ordering conditions and constraints under which messages are exchanged, is produced that describes, from a global viewpoint [...] observable behaviour of all the parties involved. Each party can then use the global definition to build and test solutions that conform to it. The global specification is in turn realised by combination of the resulting local systems [...]”



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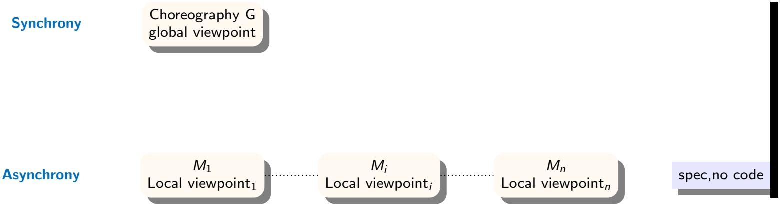

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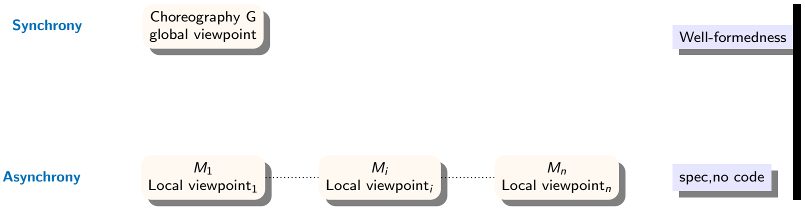

“Top-down” & “Bottom-up”

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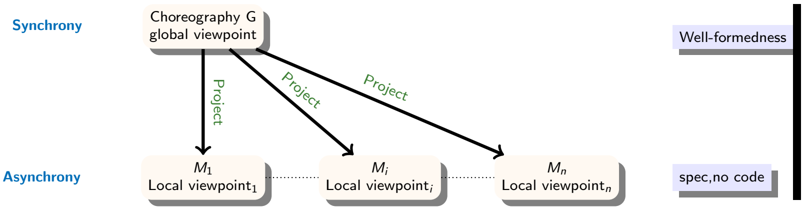

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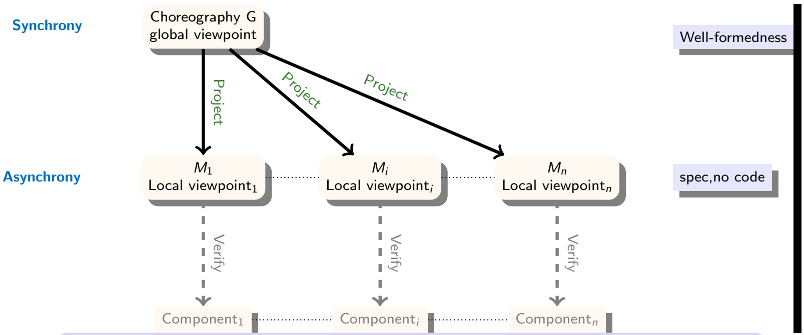
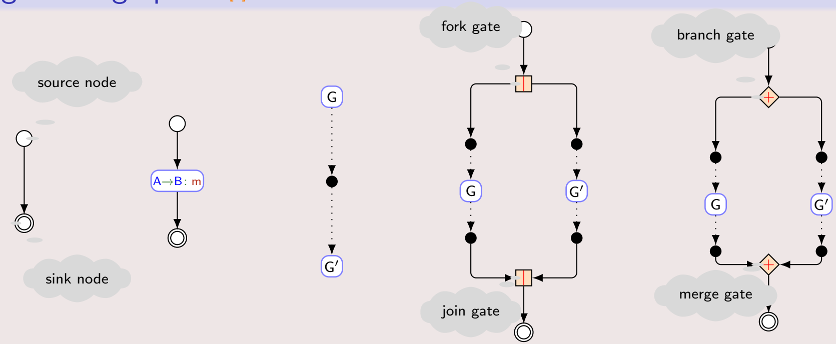


bottom-up

Extract from each component its local viewpoint, combine the local view points in a choreography...if that makes sense [?]

Global views, intuitively

g-choreographies [?]

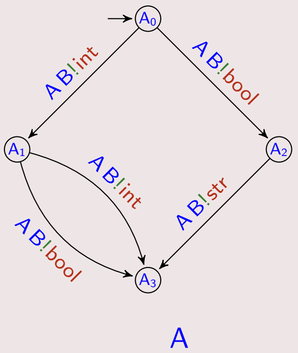


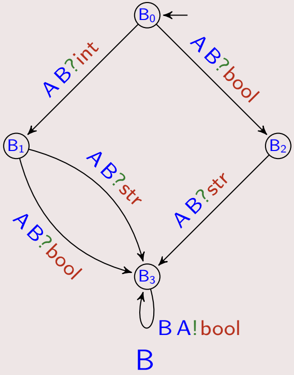
Pomset or (Event Structure[a])

[a] See Ugo de'Liguoro's talk @ ICE 2020

Local views, intuitively

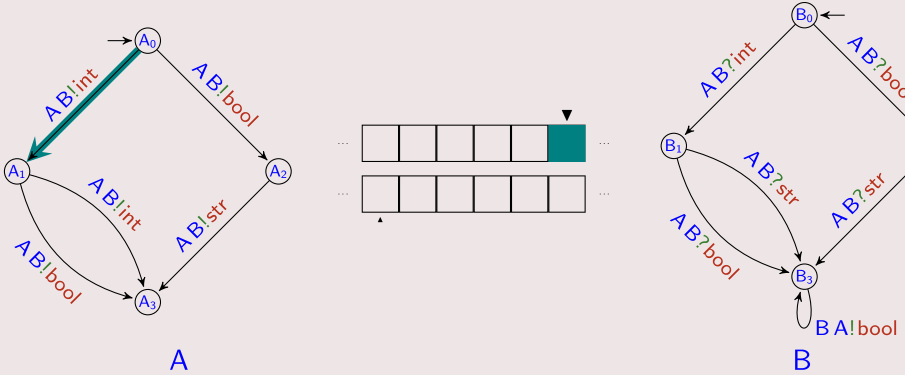
Communicating systems [?]





Local views, intuitively

Communicating systems [?]



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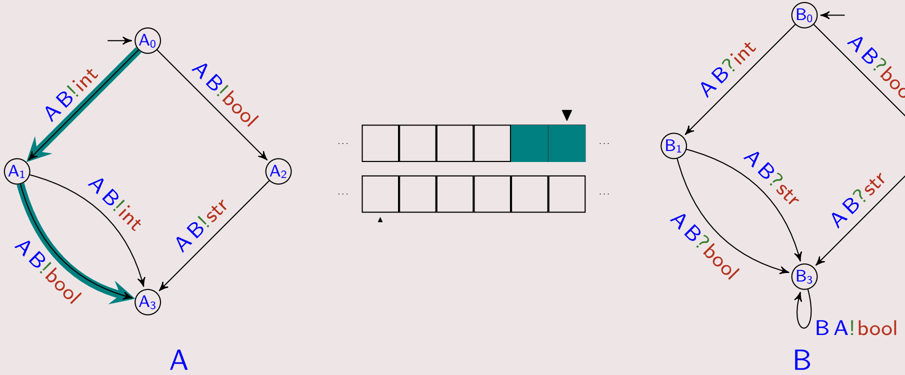
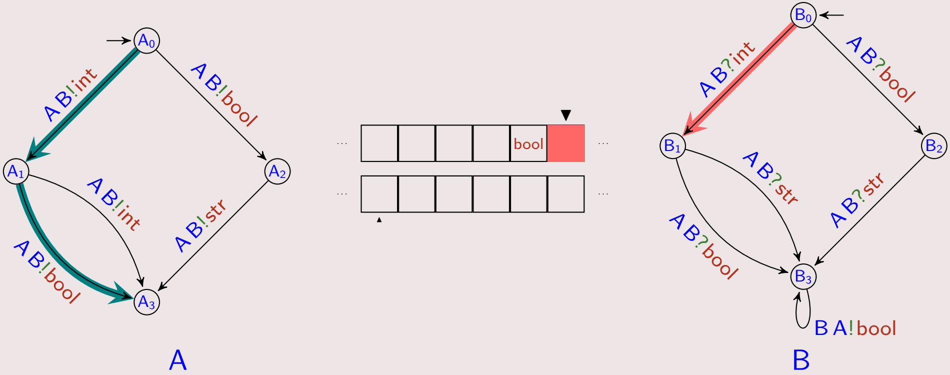
Communicating systems [?]



Local views, intuitively

Communicating systems [?]



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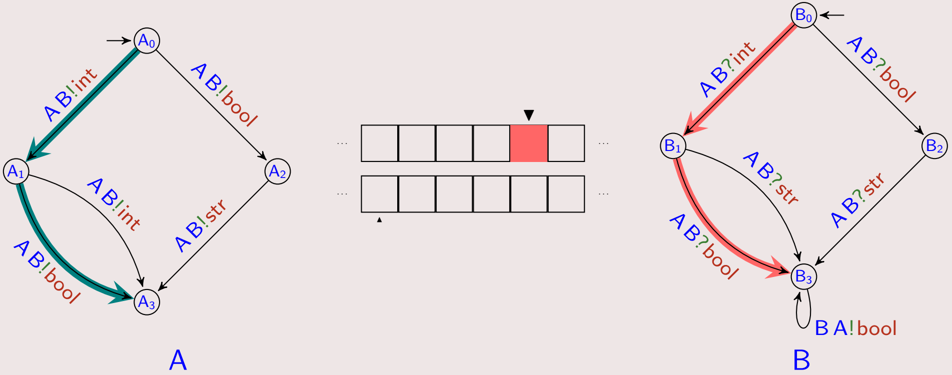

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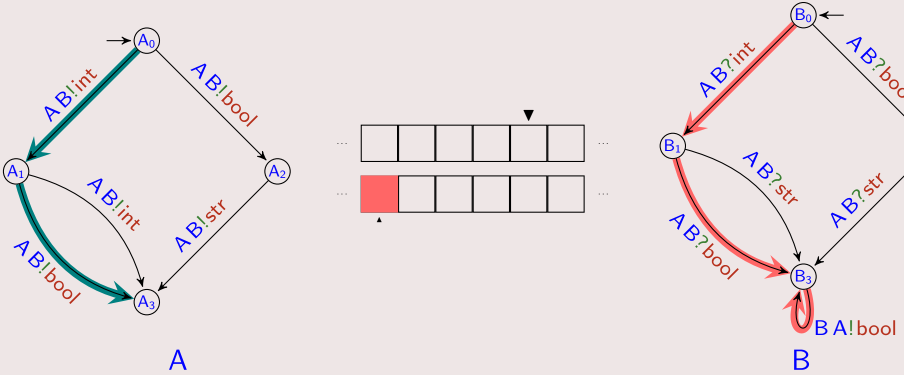

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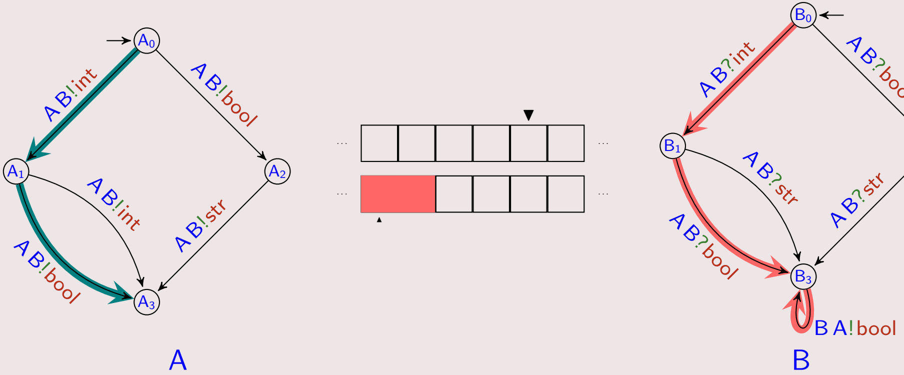

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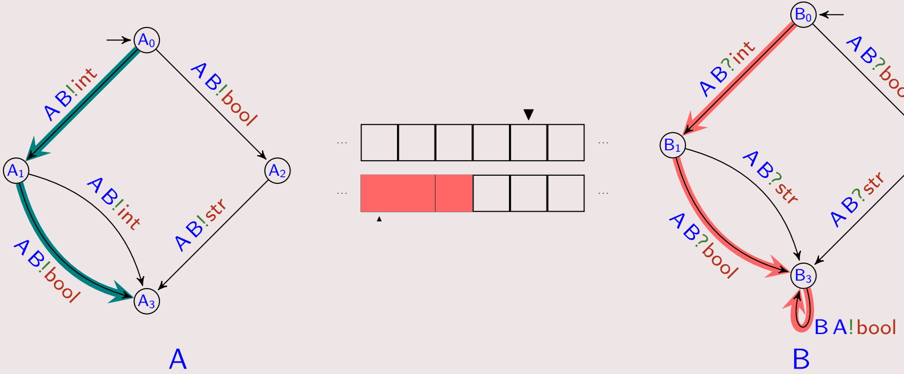

Well-formedness, intuitively

To G or not to G?

Ehm...in a distributed choice $\mathsf{G}_1 + \mathsf{G}_2 + \cdots$

- there should be one active participant
- any non-active participant should be passive decides which branch to take in a choice

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Def. A is active when it locally decides which branch to take in a choice

Def. B is passive when

- either B behaves uniformly in each branch
- or B "unambiguously understands" which branch A opted for through the information received on each branch

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Well-branchedness

When the above holds true for each choice, the choreography is well-branched. This enables correctness-by-design.

Class test

Figure out the graphical structure of the following terms and for each of them say which one is well-branched

- $G_1 = A \to B : \text{int} + A \to B : \text{str}$
- $G_2 = A \to B : \text{int} + \circledcirc$
- $G_3 = A \to B : \text{int} + A \to C : \text{str}$
- $G_4 = \left(\begin{array}{l} A \to C : \text{int};\ A \to B : \text{bool} \\ \quad + \\ A \to C : \text{str};\ A \to C : \text{bool};\ A \to B : \text{bool} \end{array} \right)$

– Act I –

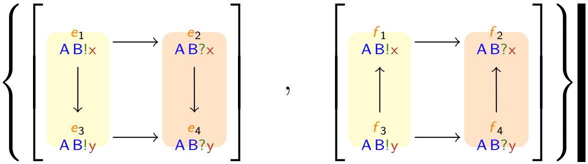
[Choregraphies, more precisely]

Syntax of g-choreographies

$$
\begin{array}{rcll}
\mathsf{G} & ::= & (\mathsf{o}) & \text{empty} \\
& | & \mathsf{A} \rightarrow \mathsf{B} : \mathsf{m} & \text{interaction} \\
& | & \mathsf{G} \mid \mathsf{G} & \text{fork} \\
& | & \mathsf{sel}\ \{\mathsf{G} + \cdots + \mathsf{G}\} & \text{choice} \\
& | & \mathsf{G}; \mathsf{G} & \text{sequential} \\
& | & \mathsf{repeat}\ \mathsf{G} & \text{iteration}
\end{array}
$$

Partially-ordered multisets [?]

Isomorphism class of labelled partially-ordered sets



- specify legit executions
- sets of alternative executions

Language of a pomset

- $e_1\ e_2\ e_3\ e_4 \rightsquigarrow$ A B!x A B?x A B!y A B?y 
- $f_3\ f_1\ f_2\ f_4 \rightsquigarrow$ A B!y A B!x A B?x A B!y 
- $e_1\ e_3\ e_2\ e_4 \rightsquigarrow$ A B!x A B!y A B?x A B?y 

Pomset semantics

The semantics of a g-choreography G

The basic idea

- is a set of pomsets
- each pomset in the set corresponds to a branch of G
- is defined by induction on the structure of G

$$
\begin{aligned}
[\![(\mathsf{o})]\!] &= \{\epsilon\} \\
[\![\mathsf{A} {\to} \mathsf{B} \colon \mathsf{m}]\!] &= \left\{\left[\ \mathsf{A\,B!m} \longrightarrow \mathsf{A\,B?m}\ \right]\right\} \\
[\![\mathsf{repeat}\ \mathsf{G}]\!] &= [\![\mathsf{G}]\!] \\
[\![\mathsf{G} \mid \mathsf{G}']\!] &= \{\mathsf{par}(r, r') \mid (r, r') \in [\![\mathsf{G}]\!] \times [\![\mathsf{G}']\!]\} \\
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$[\![\mathsf{G}]\!] = \cdots, [\,\vdots\,], \cdots$ $\qquad$ $[\![\mathsf{G}']\!] = \cdots, [\,\vdots\,], \cdots$

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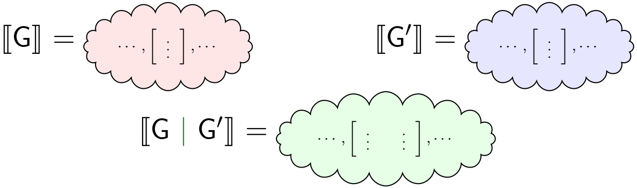

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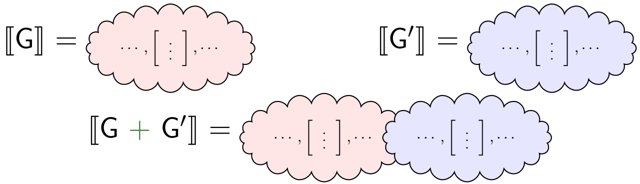
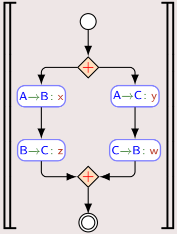


Some examples

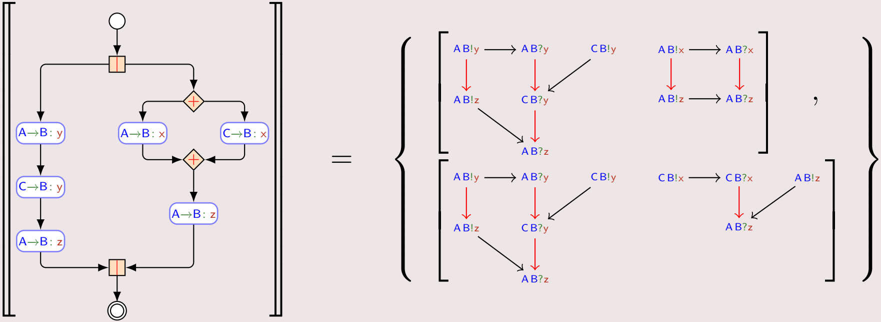
Choice & Sequential



$$= \left\{ \begin{bmatrix} \mathsf{A\,B!x} \\ \downarrow \\ \mathsf{A\,B?x} \\ \downarrow \\ \mathsf{B\,C!z} \\ \downarrow \\ \mathsf{B\,C?z} \end{bmatrix} , \begin{bmatrix} \mathsf{A\,C!y} \\ \downarrow \\ \mathsf{A\,C?y} \\ \downarrow \\ \mathsf{C\,B!w} \\ \downarrow \\ \mathsf{C\,B?w} \end{bmatrix} \right\}$$

Some examples

Parallel & choice



Realisability

Put simply...

A set of pomsets R is *realizable* if there is a deadlock-free[a] communicating system whose language is $\mathcal{L}(R)$.

[a] A system S is *deadlock-free* if none of its reachable configurations s is a deadlock, that is $s \not\rightarrow$ and either some buffers are not empty or some CFSMs have transitions from their state in s.

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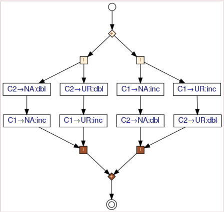
Trivial non-realisability

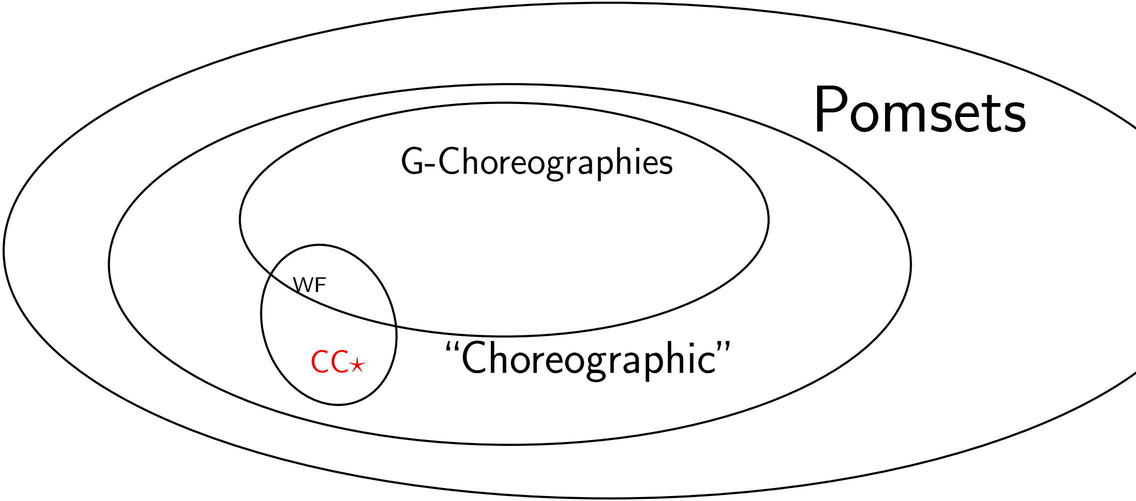
A B?m $\longrightarrow$ B C?n

Communicating systems "start" with outputs!

Non-trivial non-realisability [?]



A taxonomy of global views



Closures

$$\left[\begin{tikzcd}
\text{A C!l1} \arrow[rr] \arrow[dd] & & \text{A C?l1} \arrow[d] & \text{A C!r1} \arrow[rr] \arrow[dd] & & \text{A C?r1} \arrow[d] \\
& \text{B C!l2} \arrow[r] \arrow[d] & \text{B C?l2} \arrow[dd] & & \text{B C!r2} \arrow[r] \arrow[d] & \text{B C?r2} \arrow[dd] \\
\text{A B!x} \arrow[r] & \text{A B?x} \arrow[d] & & \text{A B!x} \arrow[r] & \text{A B?x} \arrow[d] & \\
& \text{B C!l3} \arrow[r] & \text{A C?l3} & & \text{B C!r3} \arrow[r] & \text{A C?r3}
\end{tikzcd}\right]$$

Closures

$$
\left[
\begin{tikzcd}
\mathrm{A\,C!l1} \arrow[rr] \arrow[dd] & & \mathrm{A\,C?l1} \arrow[d] & \mathrm{A\,C!r1} \arrow[rr] \arrow[dd] & & \mathrm{A\,C?r1} \arrow[d] \\
& \mathrm{B\,C!l2} \arrow[r] \arrow[d] & \mathrm{B\,C?l2} \arrow[dd] & & \mathrm{B\,C!r2} \arrow[r] \arrow[d] & \mathrm{B\,C?r2} \arrow[dd] \\
\mathrm{A\,B!x} \arrow[r] & \mathrm{A\,B?x} \arrow[d] & & \mathrm{A\,B!x} \arrow[r] & \mathrm{A\,B?x} \arrow[d] & \\
& \mathrm{B\,C!l3} \arrow[r] & \mathrm{A\,C?l3} & & \mathrm{B\,C!r3} \arrow[r] & \mathrm{A\,C?r3}
\end{tikzcd}
\right]
$$

$$
\begin{tikzcd}
\mathrm{A\,C!l1} \arrow[d] & \mathrm{A\,C!r1} \arrow[d] \\
\mathrm{A\,B!x} & \mathrm{A\,B!x}
\end{tikzcd}
\qquad
\begin{tikzcd}
\mathrm{B\,C!l2} \arrow[d] & \mathrm{B\,C!r2} \arrow[d] \\
\mathrm{A\,B?x} \arrow[d] & \mathrm{A\,B?x} \arrow[d] \\
\mathrm{B\,C!l3} & \mathrm{B\,C!r3}
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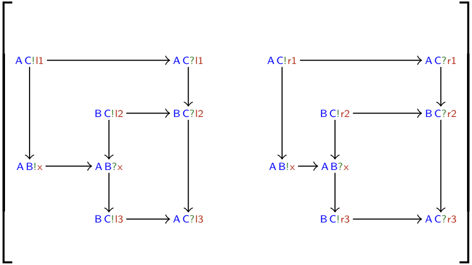
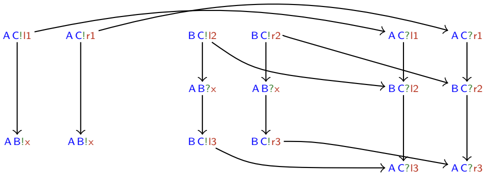


A C!l1
A C?l1
B C!l2
B C?l2
A B!x
A B?x
B C!l3
A C?l3
A C!r1
A C?r1
B C!r2
B C?r2
A B!x
A B?x
B C!r3
A C?r3



A C!l1
A C!r1
B C!l2
B C!r2
A C?l1
A C?r1
A B?x
A B?x
B C?l2
B C?r2
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A B!x
B C!l3
B C!r3
A C?l3
A C?r3

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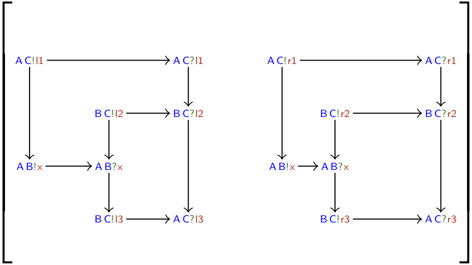

A C!l1
A C?l1
B C!l2
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A B?x
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A C!r1
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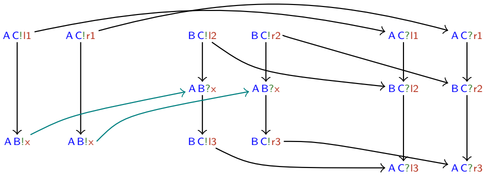

A C!l1
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B C!l2
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A C?r1
A B?x
A B?x
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B C!r3
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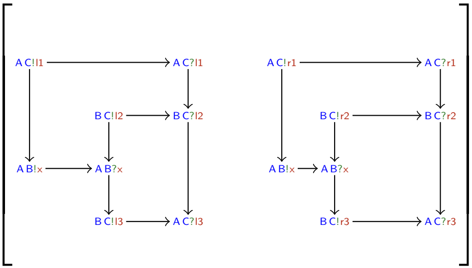

A C!l1
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B C!l2
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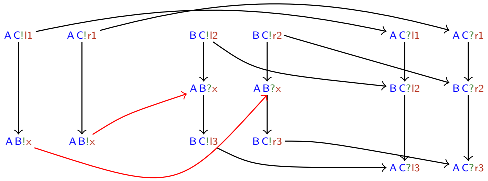
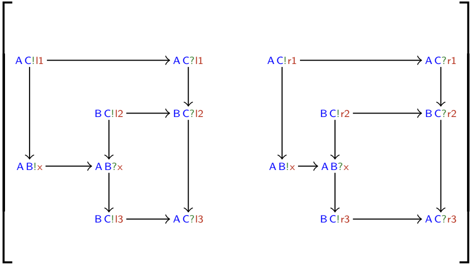
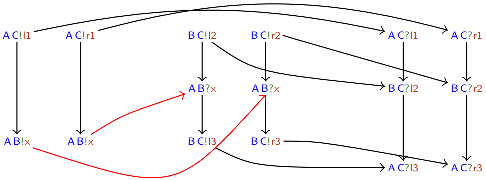
A B!x
A B?x
B C!l3
A C?l3
A C!r1
A C?r1
B C!r2
B C?r2
A B!x
A B?x
B C!r3
A C?r3



A C!l1
A C!r1
B C!l2
B C!r2
A C?l1
A C?r1
A B?x
A B?x
B C?l2
B C?r2
A B!x
A B!x
B C!l3
B C!r3
A C?l3
A C?r3

Closures





CC*-POM

Take a set of pomsets R

Choose a pomset $\bar{r}^{A} \in R$ for each participant

less permissive

Def. R is CC2-POM if $\forall r \in \Box((r^{A}\restriction_{A})_{A \in \mathcal{P}}) \ : \ \exists r' \in R \ : \ r \sqsubseteq r'$

Choose a prefix $\bar{r}^{A}$ of a pomset in R for each participant A

Def. R is CC3-POM if $\forall \bar{r} \in \Box((\bar{r}^{A}\restriction_{A})_{A \in \mathcal{P}}) \ : \ \exists r' \in R, \bar{r}' \text{ prefix of } r' \ : \ \bar{r} \sqsubseteq \bar{r}'$

Class test : solutions

Which of the following g-choreographies is well-branched?

- $\mathsf{G}_1 = \mathsf{A} \to \mathsf{B} \colon \mathsf{int} + \mathsf{A} \to \mathsf{B} \colon \mathsf{str}$
- $\mathsf{G}_2 = \mathsf{A} \to \mathsf{B} \colon \mathsf{int} + \circledcirc$
- $\mathsf{G}_3 = \mathsf{A} \to \mathsf{B} \colon \mathsf{int} + \mathsf{A} \to \mathsf{C} \colon \mathsf{str}$
- $\mathsf{G}_4 = \left(\begin{array}{l} \mathsf{A} \to \mathsf{C} \colon \mathsf{int}; \mathsf{A} \to \mathsf{B} \colon \mathsf{bool} \\ \ + \\ \mathsf{A} \to \mathsf{C} \colon \mathsf{str}; \mathsf{A} \to \mathsf{C} \colon \mathsf{bool}; \mathsf{A} \to \mathsf{B} \colon \mathsf{bool} \end{array} \right)$

Class test : solutions

Which of the following g-choreographies is well-branched?

- $G_1 = A \to B : \text{int} + A \to B : \text{str}$
- $G_2 = A \to B : \text{int} + \circledcirc$
- $G_3 = A \to B : \text{int} + A \to C : \text{str}$
- $G_4 = \left(\begin{array}{l} A \to C : \text{int};\, A \to B : \text{bool} \\ \quad + \\ A \to C : \text{str};\, A \to C : \text{bool};\, A \to B : \text{bool} \end{array} \right)$

Class test : solutions

Which of the following g-choreographies is well-branched?

- $\mathsf{G}_1 = \mathsf{A} \to \mathsf{B} : \mathsf{int} + \mathsf{A} \to \mathsf{B} : \mathsf{str}$
- $\mathsf{G}_2 = \mathsf{A} \to \mathsf{B} : \mathsf{int} + \circledcirc$
- $\mathsf{G}_3 = \mathsf{A} \to \mathsf{B} : \mathsf{int} + \mathsf{A} \to \mathsf{C} : \mathsf{str}$
- $\mathsf{G}_4 = \left(\begin{array}{l} \mathsf{A} \to \mathsf{C} : \mathsf{int}; \mathsf{A} \to \mathsf{B} : \mathsf{bool} \\ \; + \\ \mathsf{A} \to \mathsf{C} : \mathsf{str}; \mathsf{A} \to \mathsf{C} : \mathsf{bool}; \mathsf{A} \to \mathsf{B} : \mathsf{bool} \end{array} \right)$

Class test : solutions

Which of the following g-choreographies is well-branched?

- $\mathsf{G}_1 = \mathsf{A} \to \mathsf{B} \colon \mathsf{int} + \mathsf{A} \to \mathsf{B} \colon \mathsf{str}$ 
- $\mathsf{G}_2 = \mathsf{A} \to \mathsf{B} \colon \mathsf{int} + \circledcirc$ 
- $\mathsf{G}_3 = \mathsf{A} \to \mathsf{B} \colon \mathsf{int} + \mathsf{A} \to \mathsf{C} \colon \mathsf{str}$ 
- $\mathsf{G}_4 = \left(\begin{array}{l} \mathsf{A} \to \mathsf{C} \colon \mathsf{int} ; \mathsf{A} \to \mathsf{B} \colon \mathsf{bool} \\ \ + \\ \mathsf{A} \to \mathsf{C} \colon \mathsf{str} ; \mathsf{A} \to \mathsf{C} \colon \mathsf{bool} ; \mathsf{A} \to \mathsf{B} \colon \mathsf{bool} \end{array} \right)$

Class test : solutions

Which of the following g-choreographies is well-branched?

- $G_1 = \mathsf{A} \to \mathsf{B} \colon \mathsf{int} + \mathsf{A} \to \mathsf{B} \colon \mathsf{str}$ 
- $G_2 = \mathsf{A} \to \mathsf{B} \colon \mathsf{int} + \circledcirc$ 
- $G_3 = \mathsf{A} \to \mathsf{B} \colon \mathsf{int} + \mathsf{A} \to \mathsf{C} \colon \mathsf{str}$ 
- $G_4 = \left(\begin{array}{l} \mathsf{A} \to \mathsf{C} \colon \mathsf{int}; \mathsf{A} \to \mathsf{B} \colon \mathsf{bool} \\ \quad + \\ \mathsf{A} \to \mathsf{C} \colon \mathsf{str}; \mathsf{A} \to \mathsf{C} \colon \mathsf{bool}; \mathsf{A} \to \mathsf{B} \colon \mathsf{bool} \end{array} \right)$ 

Class test : solutions

Which of the following g-choreographies is well-branched?

- $G_1 = A{\to}B : \mathsf{int} + A{\to}B : \mathsf{str}$ 
- $G_2 = A{\to}B : \mathsf{int} + \circledcirc$ 
- $G_3 = A{\to}B : \mathsf{int} + A{\to}C : \mathsf{str}$ 
- $G_4 = \left(\begin{array}{l} A{\to}C : \mathsf{int}; A{\to}B : \mathsf{bool} \\ \quad + \\ A{\to}C : \mathsf{str}; A{\to}C : \mathsf{bool}; A{\to}B : \mathsf{bool} \end{array} \right)$ 

Find out which closure conditions the non well-branched properties violate

– Act II –

[An exercise: prototype tool support]