A MODULAR LTS FOR OPEN REACTIVE SYSTEMS

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Outline

- Process calculi
- (Open) Reactive Systems
- A Few Problems
- Some Solutions
- Conclusions

A process calculus: CCS

- Syntax

P ::= M, P_1 | P_2 M ::= **0**, c

- Labelled Transition System P $\xrightarrow{\delta}$ Q

$$\frac{}{\delta.P \xrightarrow{\delta} P}$$

$$\frac{P \xrightarrow{a} Q,\ R \xrightarrow{\bar{a}} \ldots}{P \mid R \xrightarrow{\tau} \ldots}$$

$$\frac{P \xrightarrow{\delta} Q}{P \mid R \xrightarrow{\delta} Q \mid R}$$

$$\frac{P \ldots}{P + R \longrightarrow \ldots}$$

Expresses how the system can interact with the environment

Expresses the behaviour of the system in terms of the behaviour of its components

- Behavioral Equivalence

A symmetric relation R is a bisimulation if when

P $\xrightarrow{\delta}$ P' implies Q $\xrightarrow{\delta}$ Q' and P' R Q'

Bisimilarity ≈ is the largest bisimulation

Compositional

Reduction semantics for CCS

- Structural Congruence

$P \mid Q \equiv Q \mid P \qquad P \mid (Q \mid R) \equiv (P \mid Q) \mid R \qquad P \mid \mathbf{0} \equiv P$

$M+N \equiv N+M \qquad M+(N+O) \equiv (M+N)+O \qquad M+\mathbf{0} =$

Elegant and natural
Describes the behaviour of the system as a whole

- Reduction Relation

$(\overline{a}.P+M) \mid (a.Q+N) \longrightarrow P \mid Q$

Closed wrt. structural congruence and parallel op

Not Compositional

$\overline{a}.\mathbf{0} \not\longrightarrow$ is equivalent to $\overline{b}.\mathbf{0} \not\longrightarrow$

$\overline{a}.\mathbf{0} \mid a.\mathbf{0} \longrightarrow \mathbf{0}$ is not equivalent to $\overline{b}.\mathbf{0} \mid a.\mathbf{0} \not\longrightarrow$

Preliminary question...

How to derive LTSs $\xrightarrow{\lambda}$ from reduction semantics such that their bisimulation is a congruence?

Reactive Systems

[Leifer and Milner 2000]

(Open) Reactive Systems

Categories model the state space of formalisms whose operational semantics is provided by reduction rules

Terms	Contexts (Open Terms)	Reduction Rules	Structural rules
$0 \xrightarrow{P} I_2$	$I_1 \xrightarrow{C} I_2$	$< I_1 \xrightarrow{\ell} I_2 \, , \, I_1 \xrightarrow{r} I_2 >$	$I_1 \overset{C}{\underset{C'}{\rightrightarrows}} I_2$, $C \Downarrow C'$

Redution Relation

$P \equiv \ell ; D \longrightarrow r ; D$

Reactive context

$a.0 \parallel \bar{a}.0 \longrightarrow 0 \parallel 0$

-|P

$a.0 \parallel \bar{a}.0 \mid P \longrightarrow 0 \parallel 0 \mid P$

b.-

$b.(a.0 \mid \bar{a}.0) \not\longrightarrow$

Open Saturated LTS

Any context

$P \xrightarrow[X]{C}_{S} Q$ iff $X;P;C \longrightarrow Q$

Any instantiation

Open Saturated bisimilarity $\sim^{SAT}$ is a congruence

Examples: CCS

<a.-,-> $\xrightarrow[\text{<-,->}]{-|\overline{a}.-}_{S}$ -|-

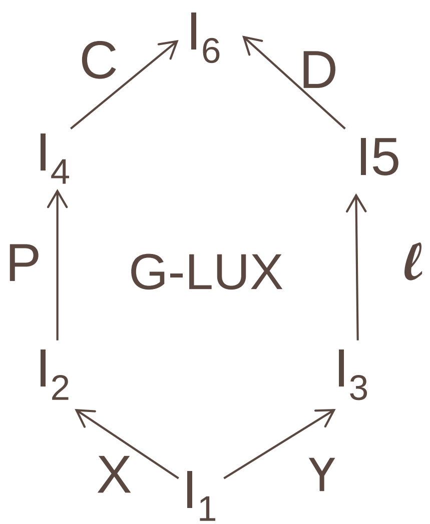
<a.-, -> $\xrightarrow[\text{<Q,->}]{-|\overline{a}.-|P}_{S}$ Q|-|P Redundant

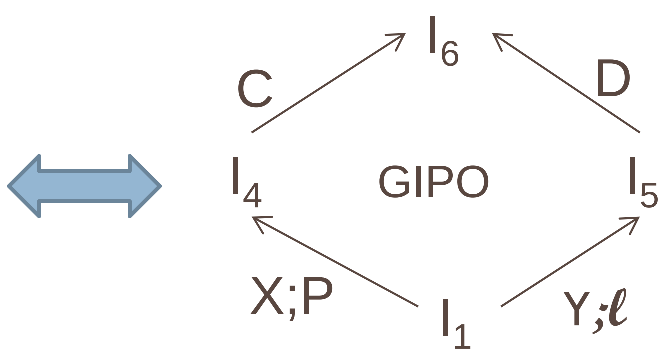
G-Lux LTS [Klin, Sassone, Sobocinski 2005]

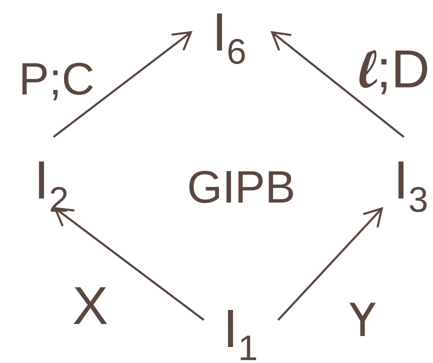
Minimal context

$$P \xrightarrow[X]{C}_{L} Q \quad \text{iff} \quad X;P;C \longrightarrow Q$$

Most general instantiation







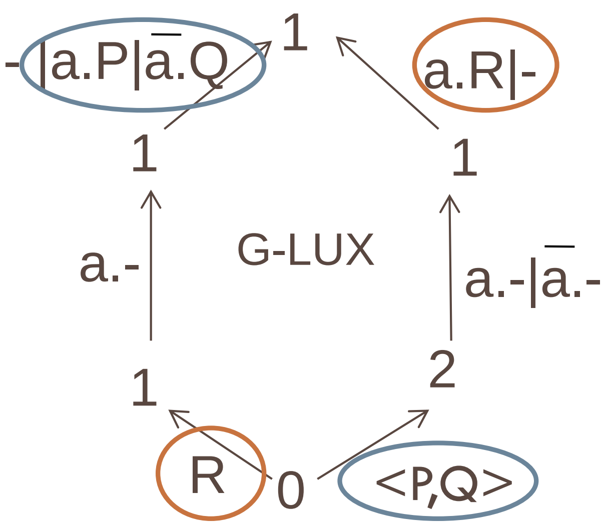
Examples: CCS

$$\langle a.-,-\rangle \xrightarrow[\langle -,-\rangle]{-\,|\,\overline{a}.-}_{L} -\,|\,-$$

$$\langle a.-, -\rangle \xrightarrow[\langle Q,-\rangle]{-\,|\,\overline{a}.-\,|\,P}_{L} Q\,|\,-\,|\,P$$ Not minimal

Problems

1. Lux bisimilarity a congruence under restrictive conditions
2. Redundancy



$$a.- \xrightarrow[R]{-\,|\,a.P\,|\,\overline{a}.Q}_{L} a.R\,|\,P\,|\,Q$$

3. Infinitary and flat presentation

Bisimilarity is not a congruence

We propose (elsewhere) a suitable notion of barbed bisimilarity for open RSs which is

- more expressive
- able to recast a variety of observational, bisimulation-based equivalence
- efficiently characterizable

Redundancy

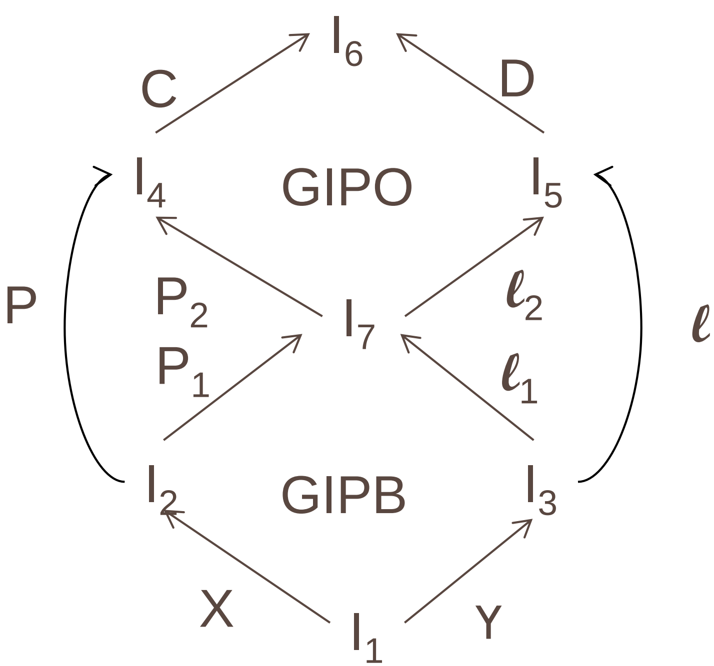
We propose an alternative way to derive LTSs

GIPO-GIPB LTS

Minimal context

$P \xrightarrow[X]{C}_{L} Q$ iff $X;P;C \longrightarrow Q$

Most general instantiation



Examples: CCS

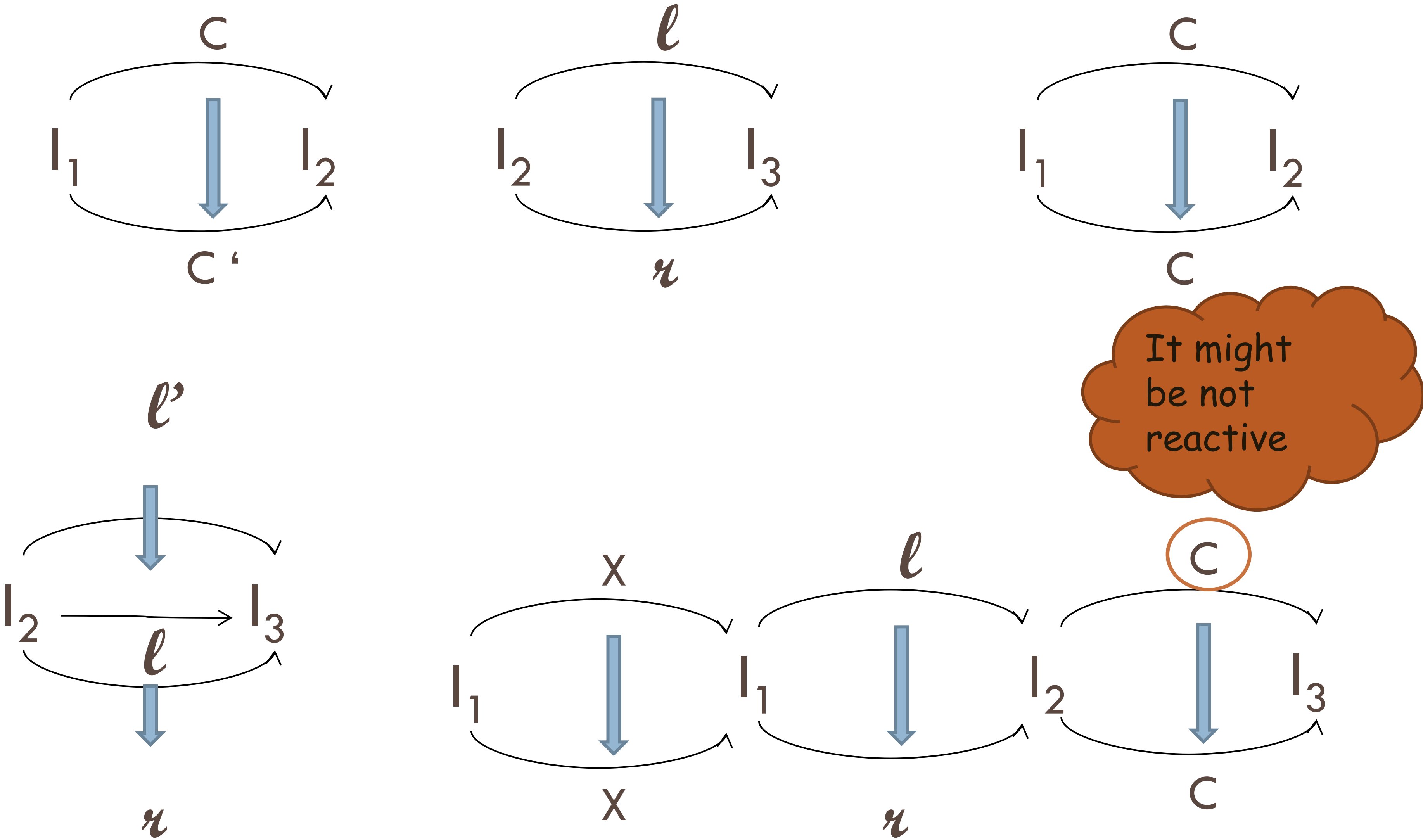
$\langle a.-,-\rangle \xrightarrow[\langle -,-\rangle]{-\,|\,\bar{a}.-}_{GG} -\,|\,-$

$a.- \xrightarrow[R]{-\,|\,a.P\,|\,\bar{a}.Q}_{GG}$ Not available

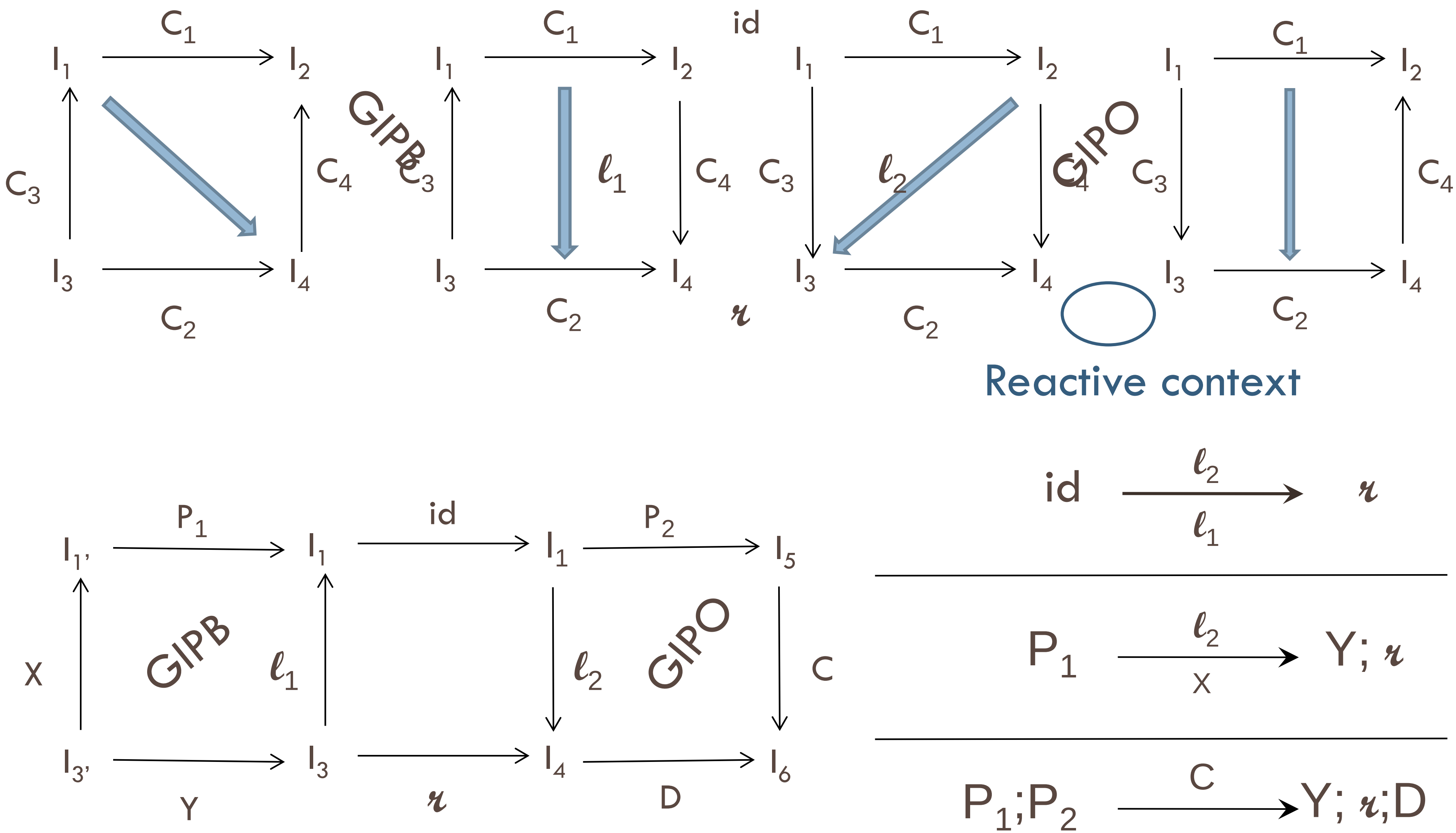
Infinitary and flat presentation

We propose a SOS-like presentation via an encoding into tile systems

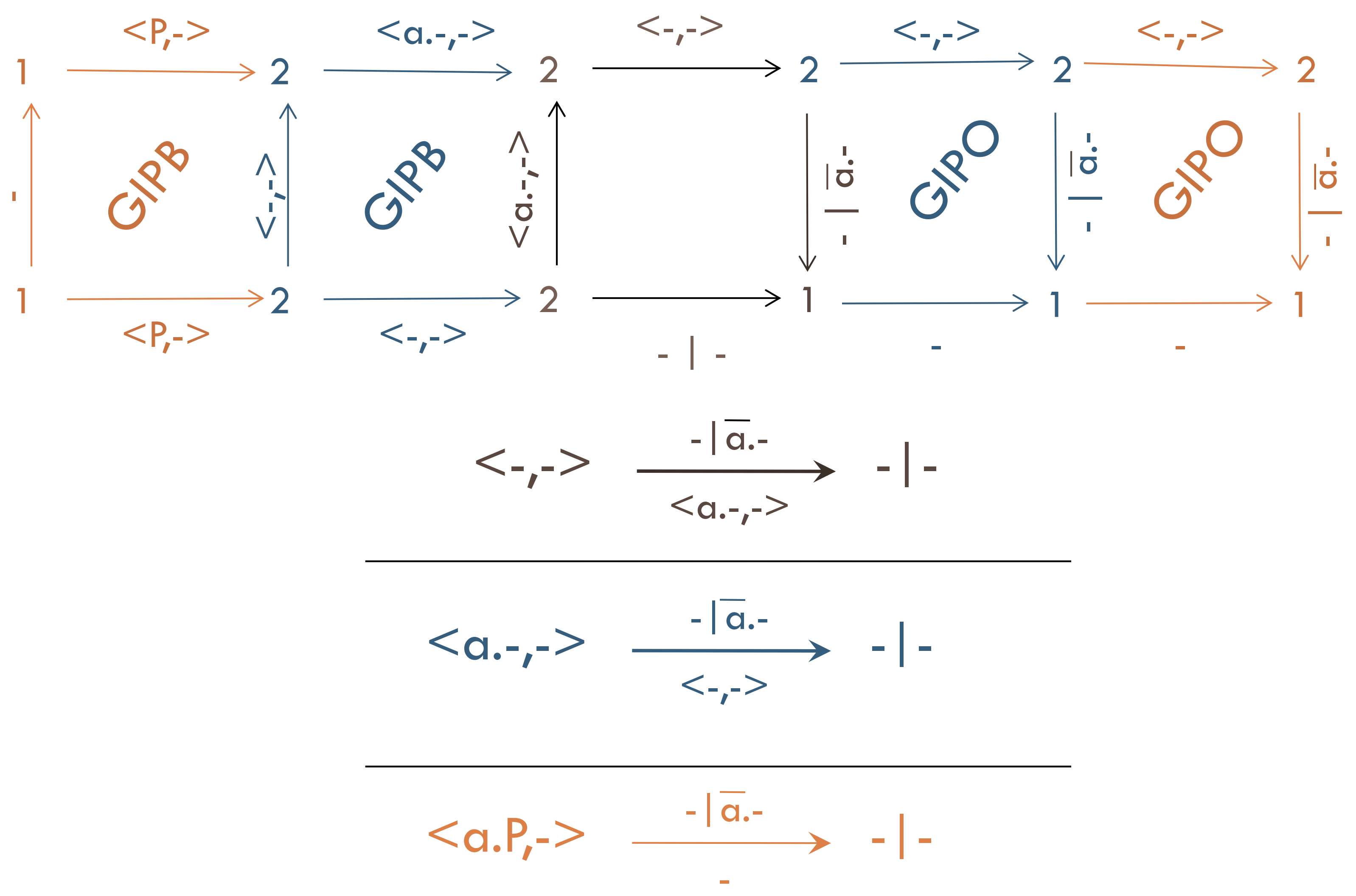
2-Category of Interactions



C-Square Double Category



Example



Conclusions

- We addressed some issues concerning the adequacy of the technique based on LUX in deriving LTSs for open RSs

- We studied three problems:
  - The induced bisimilarity in not always a congruence
  - The derived LTS is redundant
  - It has a flat and infinitary presentation

- Future work
  - Finding a suitable notion of bisimilarity on the GIPO-GIPB LTS
  - Extending our framework by considering an automatically derived notion of barb for reactive systems