Realisability of Global Models of Interaction

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FMT, CNR–ISTI, Pisa, Italy

T-LADIES 1st year meeting, Catania, October 12th, 2023

Outline

- Team Automata and other Coordination Models
- Realisability of Team Automata
- Acknowledgements

Team Automata and other Coordination Models

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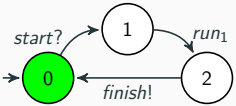

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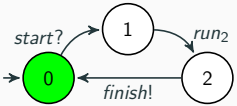

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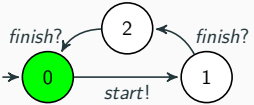

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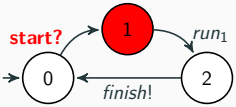

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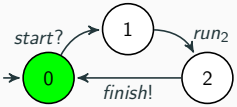

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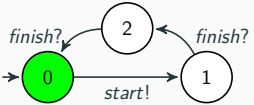

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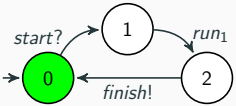

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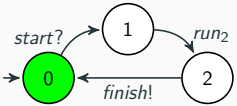

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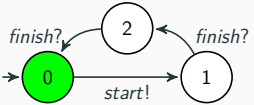

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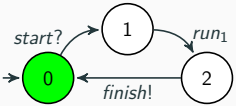

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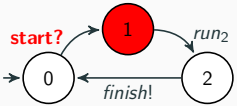

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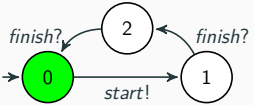

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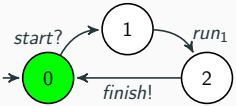

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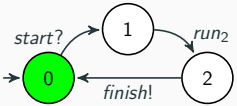

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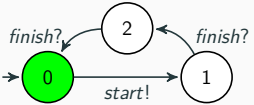

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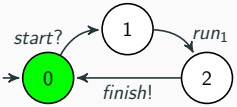

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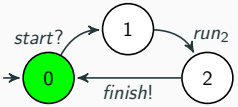

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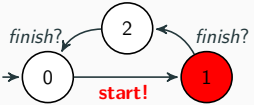

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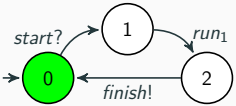

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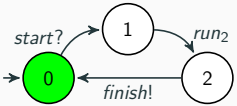

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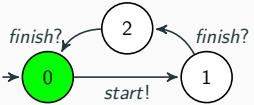

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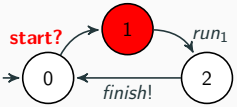

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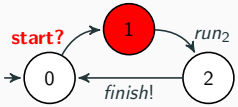

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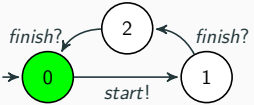

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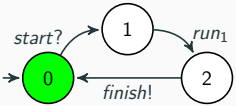

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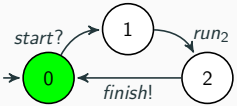

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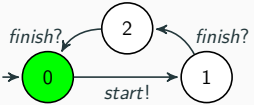

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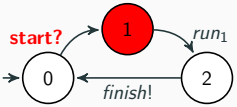

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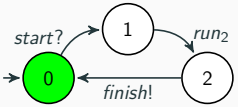

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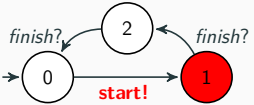

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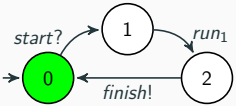

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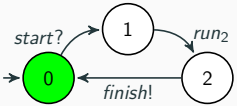

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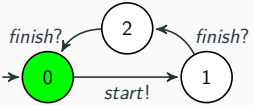

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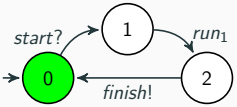

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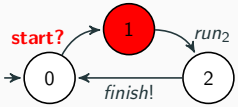

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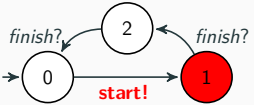

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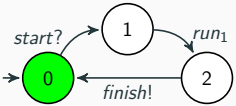

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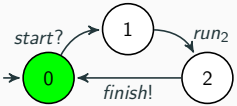

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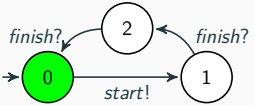

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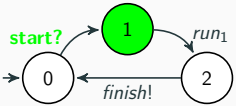

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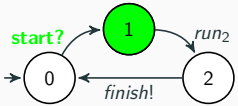

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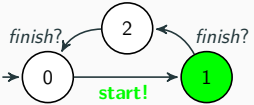

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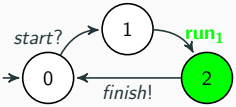

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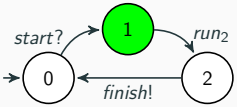

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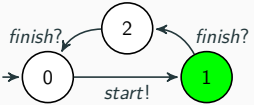

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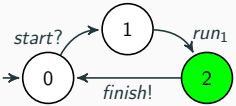

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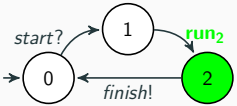

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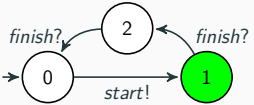

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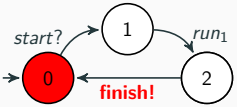

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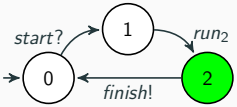

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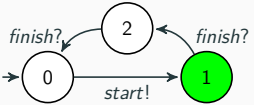

Controller

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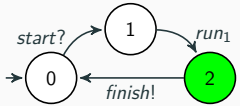

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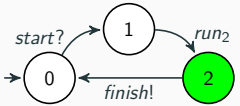

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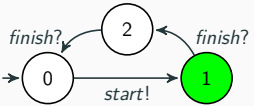

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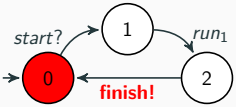

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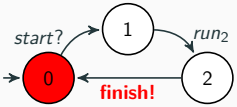

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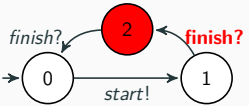

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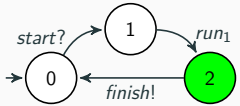

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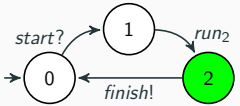

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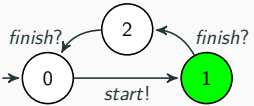

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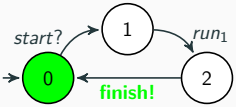

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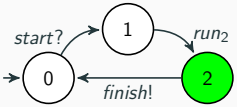

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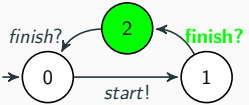

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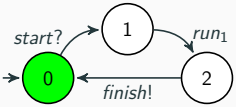

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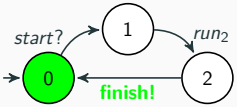

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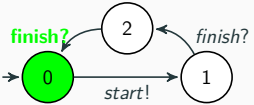

Controller

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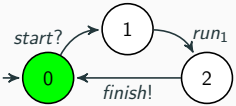
Team Automata: Constrained Multiparty Synchronisations



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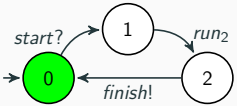

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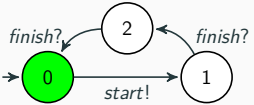

Controller

Team Automata synchronisations:

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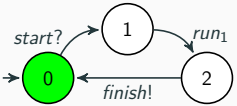

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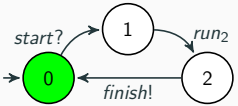

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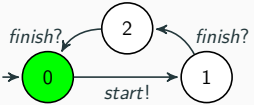

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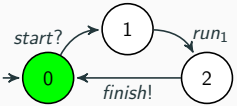
multiparty

Ctr $\rightarrow \{R1, R2\}$: start

Team Automata: Constrained Multiparty Synchronisations



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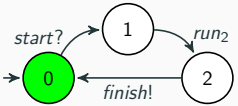

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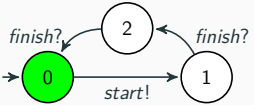

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multiparty

Ctr $\rightarrow \{R1, R2\}$: start

constrained

start: $1 \rightarrow 2$
finish: $1 \rightarrow 1$

Overview on Constrained Multiparty Synchronisation in Team Automata

J. Proença @ FACS'23

Overview on Constrained Multiparty Synchronisation in Team Automata

and other coordination models!

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and other coordination models: J. Proença @ FACS'23

Runners with orchestrators

- Reo
- BIP

↳ S.-S.T.Q. Jongmans and F. Arbab, Overview of thirty semantic formalisms for Reo. *Scientific Annals of Computer Science* 22 (2012)

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Runners with choreographies

- Choreographic Automata (CA)
- Multiparty Session Types (MPST)

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S. Ghilezan, S. Jakšić, J. Pantović, A. Scalas, and N. Yoshida, Precise subtyping for synchronous multiparty sessions. *Journal of Logical and Algebraic Methods in Programming* 104 (2019)

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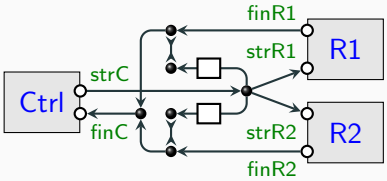
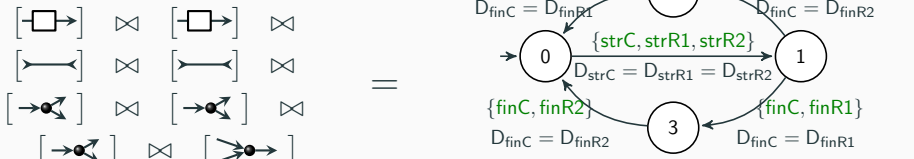
Realisability

- challenge
- solution

Orchestrators: Reo

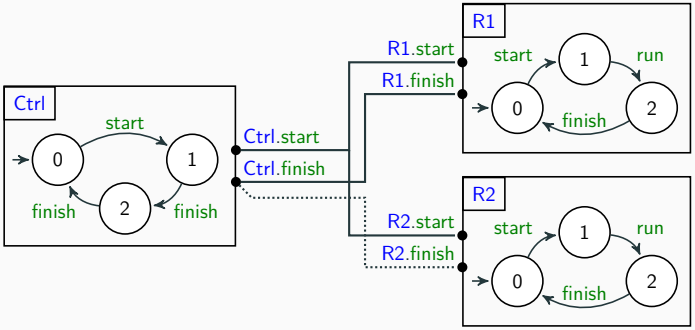


- Focus on connectors (not on components)
- Connectors built compositionally
- Components should be flexible/compatible



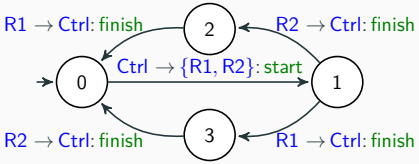
(Semantics with Constraint Automata)

Orchestrators: BIP

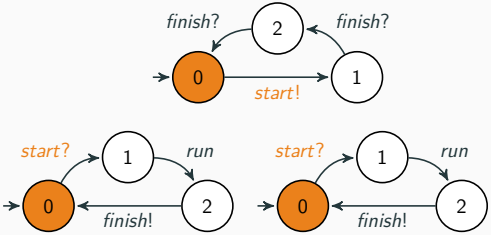


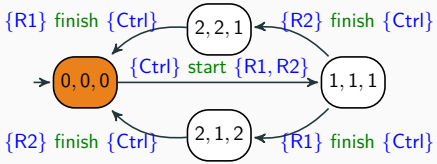
- components expose ports
- interactions restrict which ports can fire
- constructors using unicast (●) and broadcast (▲) can be used to restrict interactions
- dataflow can be added

Choreographies: Choreography Automata (CA)



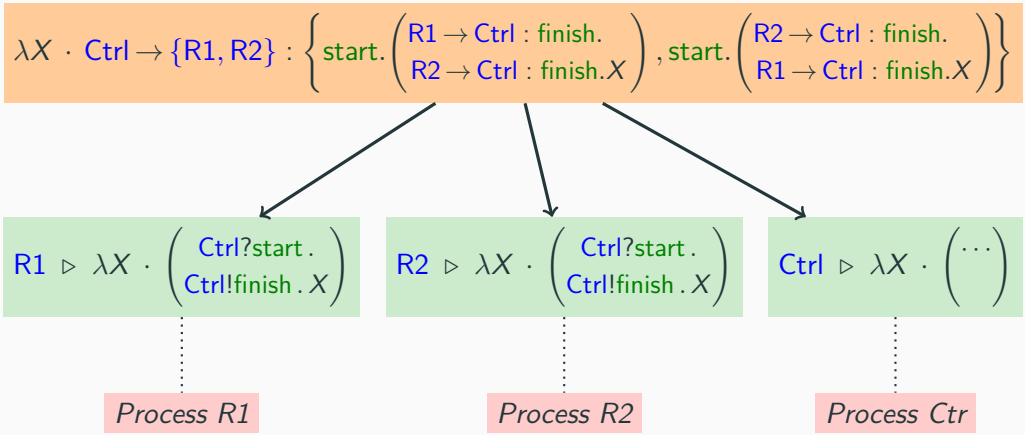
- Many results over the language of CA
- Projections of the language of CA





(Composed Team Automaton)

Choreographies: Multiparty Session Types (MPST)



Realisability of Team Automata

Challenge

How to check if a global model is realisable and, if it is, how to synthesise a realisation?

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$$\mathcal{M} \textit{ realised by } \mathcal{S} = (\mathcal{M}_i)_{i \in \mathcal{I}} ?$$

Solutions typically impose syntactic restrictions on global types, using projections to obtain local models:

F. Barbanera, I. Lanese, and E. Tuosto, Formal Choreographic Languages @ COORDINATION'22

M. Hüttel et al., Foundations of Session Types and Behavioural Contracts. *ACM Comput. Surv.* 49 (2016)

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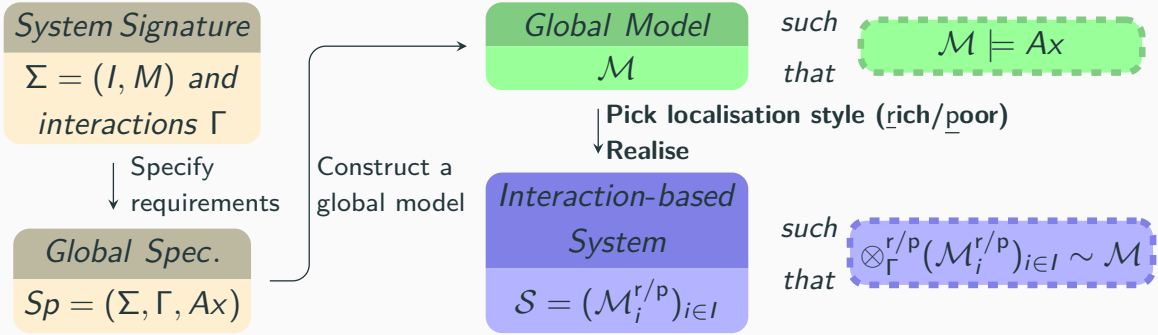
$$\otimes(\mathcal{M}_i)_{i \in \mathcal{I}} \models Sp \, ?$$

Alternatively, provide a specification in some logical formalism, and construct local models from scratch:

R. Hennicker, Role-Based Development of Dynamically Evolving Esembles @ WADT'18

Contribution



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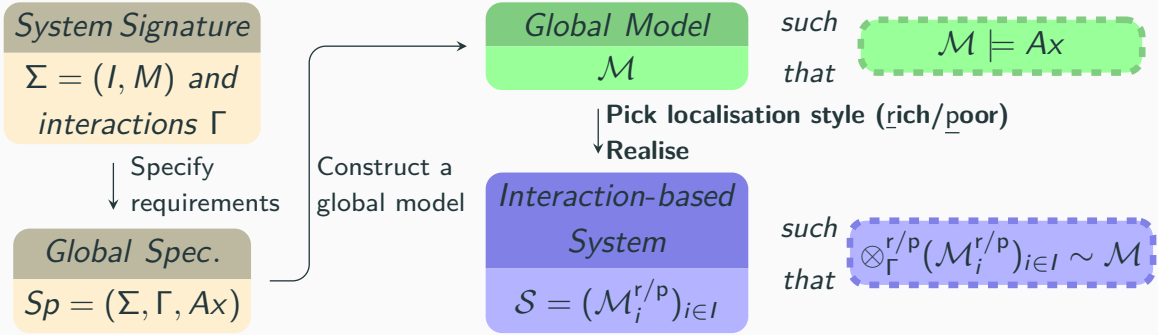


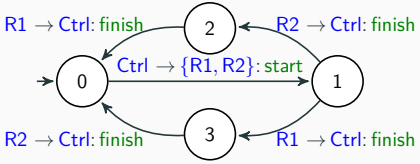
Multi-interactions

rich (à la multi-party session types, choreography languages) $i \to j : m \Rightarrow$ local output action $i\,j\,!\,m$ for i and local input action $i\,j\,?\,m$ for j

poor (à la component-based I/O development, loose coupling) $i \to j : m \Rightarrow$ local output action $!m$ for i and local input action $?m$ for j

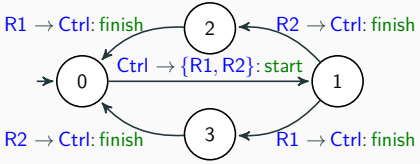
Example

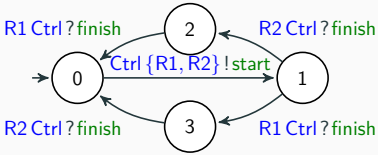
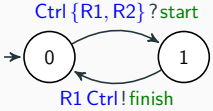
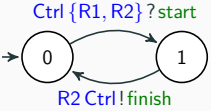
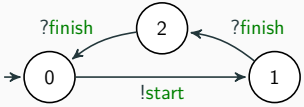
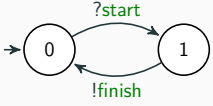
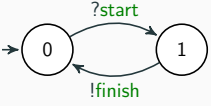
Recall:



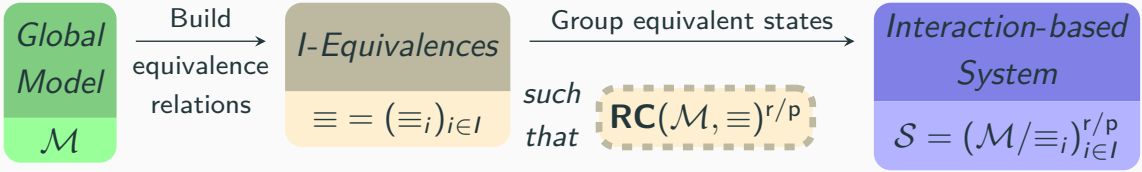
Example

Recall:



Localisation	Local Ctrl	Local R1	Local R2
Rich			
Poor			

Check realisability and system synthesis



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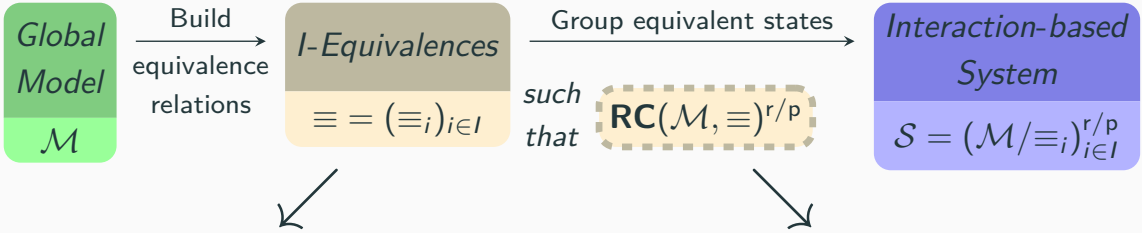
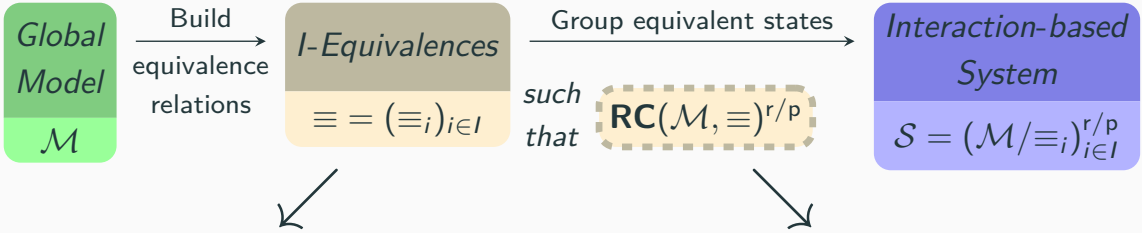


I. Castellani, M. Mukund, and P.S. Thiagarajan,
Synthesizing Distributed Transition Systems
from Global Specifications @ FSTTCS'99

cf. our paper for details:
M.H. ter Beek, R. Hennicker, and J. Proença,
Realisability of Global Models of Interaction @ ICTAC'23

Check realisability and system synthesis



I. Castellani, M. Mukund, and P.S. Thiagarajan, Synthesizing Distributed Transition Systems from Global Specifications @ FSTTCS'99

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Theorems 2/3

If $RC(\mathcal{M}, \equiv)^{\mathsf{r/p}}$ holds, then $\mathcal{M} \sim \otimes_{\Gamma}^{\mathsf{r/p}}((\mathcal{M}/\equiv_i)^{\mathsf{r/p}})_{i \in I}$

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3. To construct realisations we consider, and analyse, two different localisation styles: rich and poor local actions
4. A prototypical tool Ceta checks the realisability conditions and, if they are satisfied, generates local quotients and hence realisations

`https://github.com/arcalab/choreo/tree/ceta`

`https://lmf.di.uminho.pt/ceta`

Choreographic Extended Team Automata

Choreography

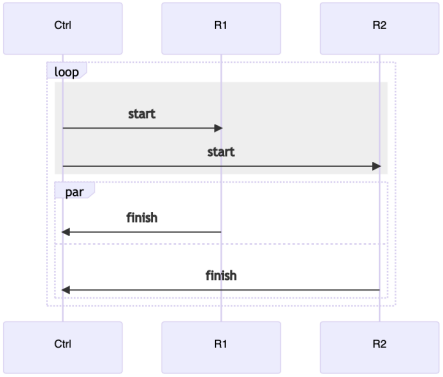
```
1 // Race example
2 (
3  (Ctrl->R1,R2: start);
4  (R1->Ctrl:finish ||
5   R2->Ctrl:finish)
6 )*
```

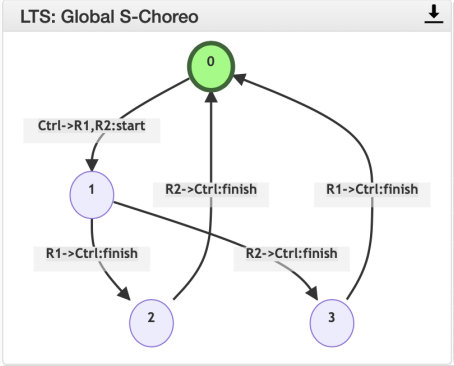
A controller starts 2 runners at the same time, and receives a finish message from each runner at a time.

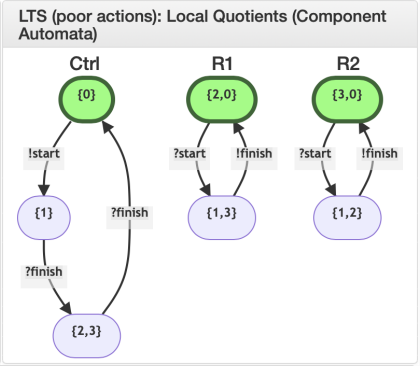
Examples

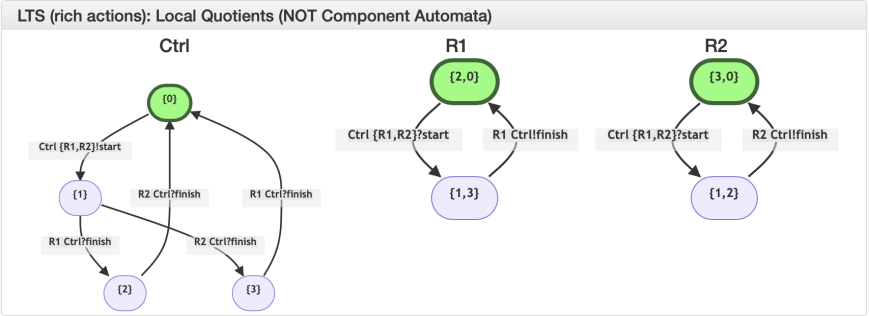
Race (simple) | Race (R1-first) | Race (once, simple)
Toss | Gossip (bad) | Gossip (good) | Cast-v1
Cast-v2 | ab+cb+ca | ab;ac | ab|ac | ab;cd | ab|cd

Sequence Diagram




LTS: Global S-Choreo
0
Ctrl->R1,R2:start
1
R2->Ctrl:finish
R1->Ctrl:finish
R1->Ctrl:finish
R2->Ctrl:finish
2
3


LTS (poor actions): Local Quotients (Component Automata)
Ctrl
R1
R2
{0}
{2,0}
{3,0}
!start
?start
!finish
?start
!finish
{1}
{1,3}
{1,2}
?finish
?finish
{2,3}


LTS (rich actions): Local Quotients (NOT Component Automata)
Ctrl
R1
R2
{0}
{2,0}
{3,0}
Ctrl {R1,R2}!start
R2 Ctrl?finish
R1 Ctrl?finish
Ctrl {R1,R2}?start
R1 Ctrl!finish
Ctrl {R1,R2}?start
R2 Ctrl!finish
{1}
{1,3}
{1,2}
R1 Ctrl?finish
R2 Ctrl?finish
{2}
{3}

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- Building local quotients differs from projections used for multi-party session types, since projections are partial operations depending on syntactic conditions, whereas we assume no restrictions on the form of global models
- However, these syntactic restrictions used for global types guarantee some kind of communication properties of a resulting system which we do not consider

Future work

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3. Consider open global models (systems) and their composition

4. Consider realisability conditions in the context of asynchronous communication

Acknowledgements

Thanks for your attention! And note that we're hiring!

And thanks to the other team members of the work presented here:

M.H. ter Beek, R. Hennicker, and J. Proença, Realisability of Global Models of Interaction @ ICTAC'23 Lima, Peru