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From Communicating Machines to Graphical Choreographies

Julien Lange
joint work with Emilio Tuosto *and* Nobuko Yoshida

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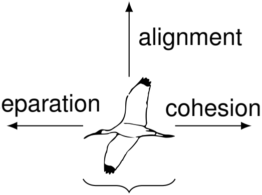

Single bird $\simeq$ local behaviour $\simeq$ CFSM

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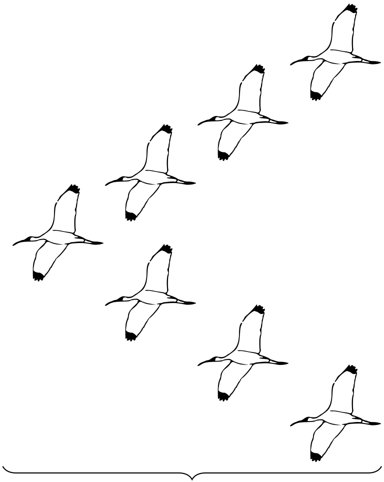
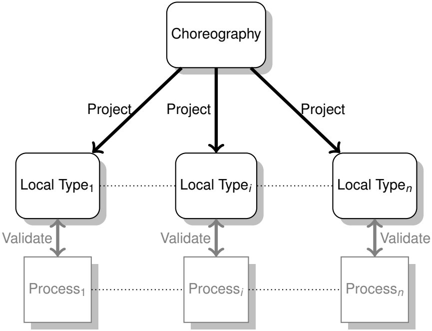


Flock $\simeq$ global behaviour $\simeq$ choreography

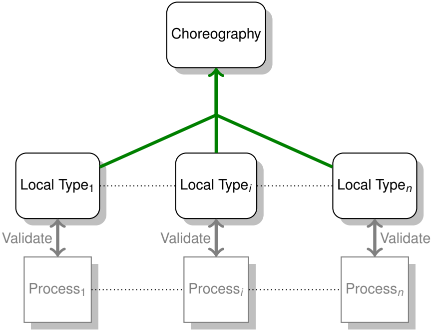
Introduction

- Parts of distributed systems change/evolve, not always in a coordinated way,
- these changes are often *not* documented.
- Service oriented systems are sometimes composed dynamically,
- it is often unclear how complex the overall system has become.
- Cognizant's Zero Deviation Lifecyle Business Unit.

A *global* point of view of a distributed system is *essential* for top-level management.

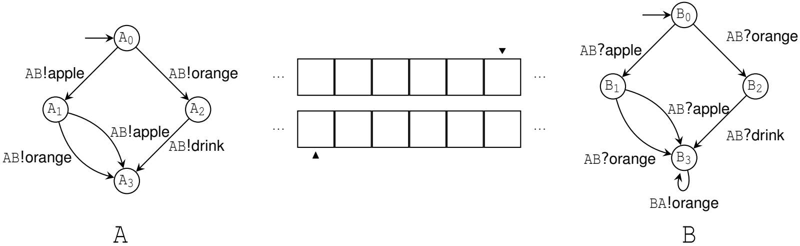


- Choreography-driven development, cf. Multiparty Session Types top-down approach (POPL'08 & ESOP'12)
- Not applicable without *a priori knowledge* of a choreography



- Choreography-driven development, cf. Multiparty Session Types top-down approach (POPL'08 & ESOP'12)
- Not applicable without *a priori knowledge* of a choreography
- Our goal: from *Communicating Finite-State Machines* to *Global Graphs*

Background: CFSMs



“On Communicating Finite-State Machines”, Brand & Zafiropulo (’83)

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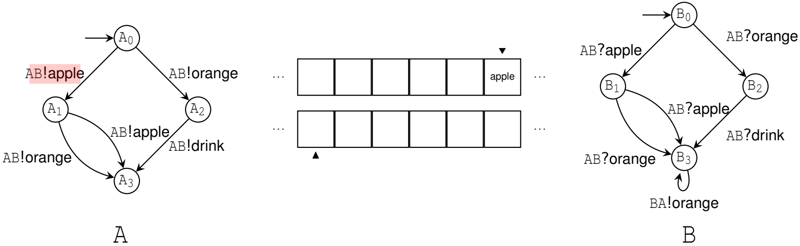

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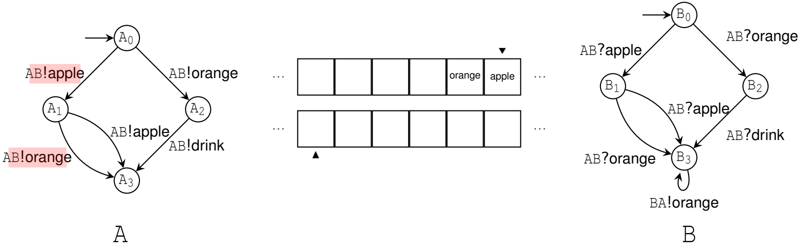

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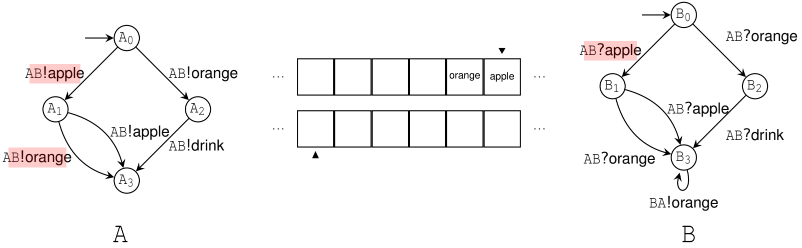

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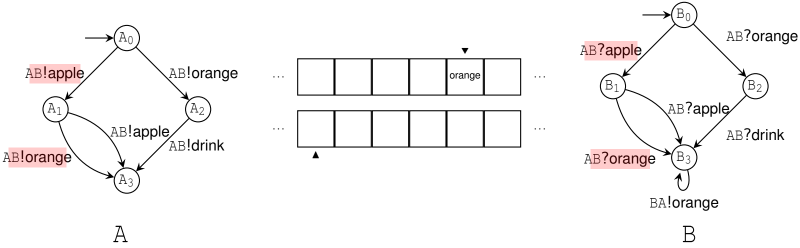

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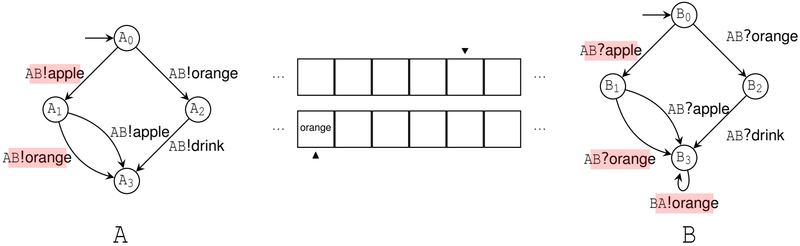

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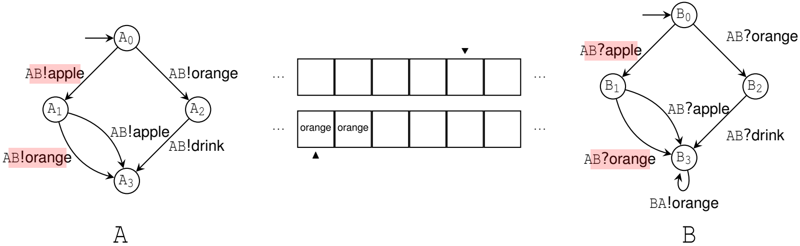

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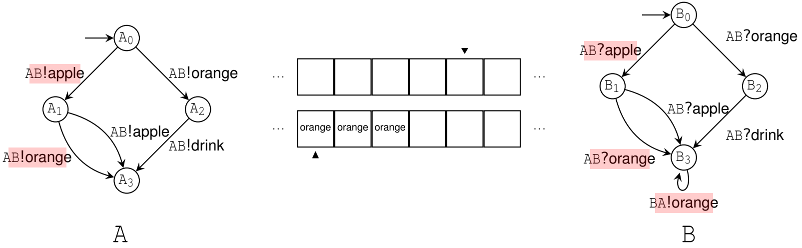

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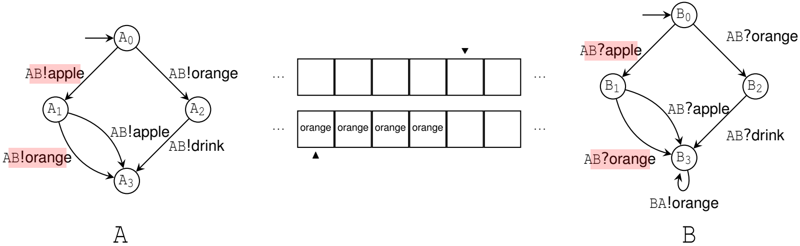

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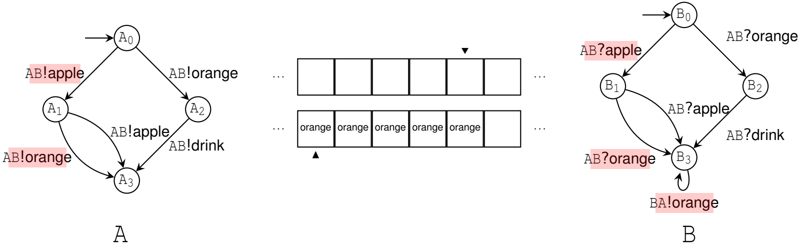

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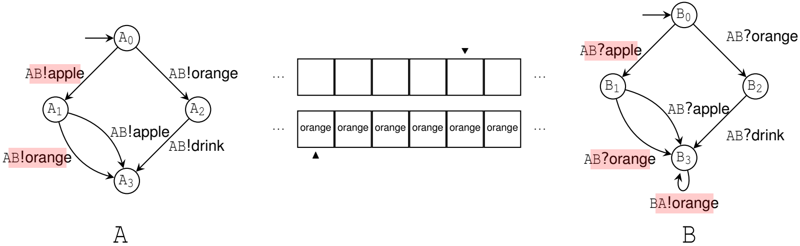

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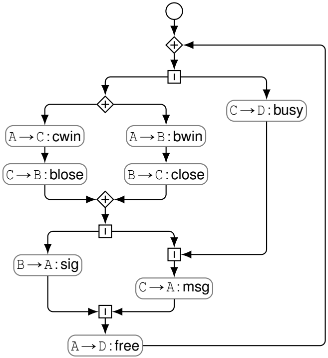
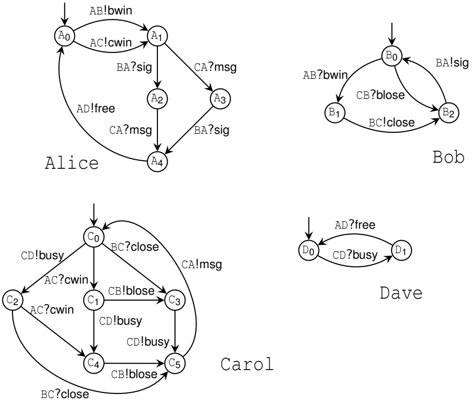
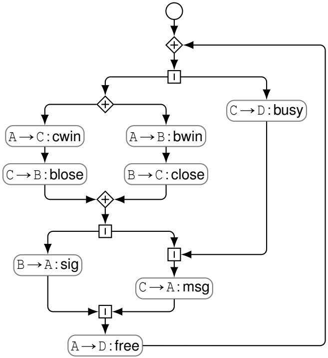
Global Graphs



Four Player Game

Global Graphs





Four Player Game

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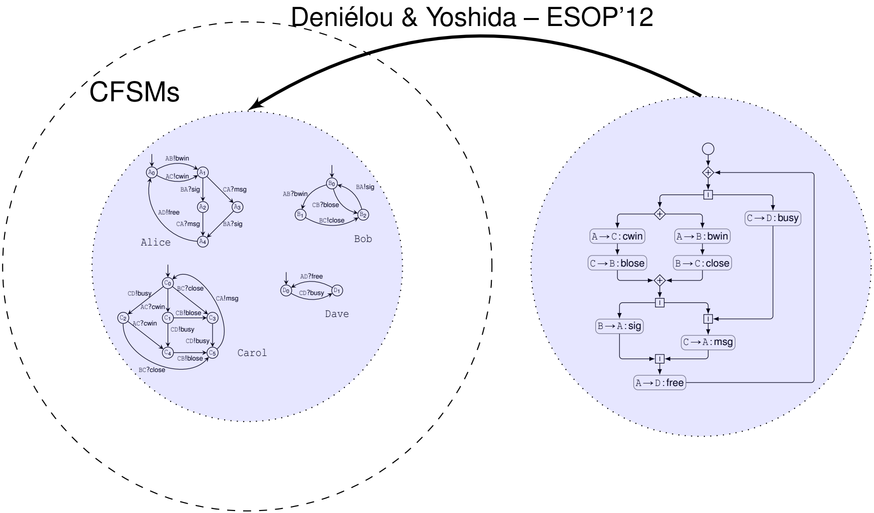
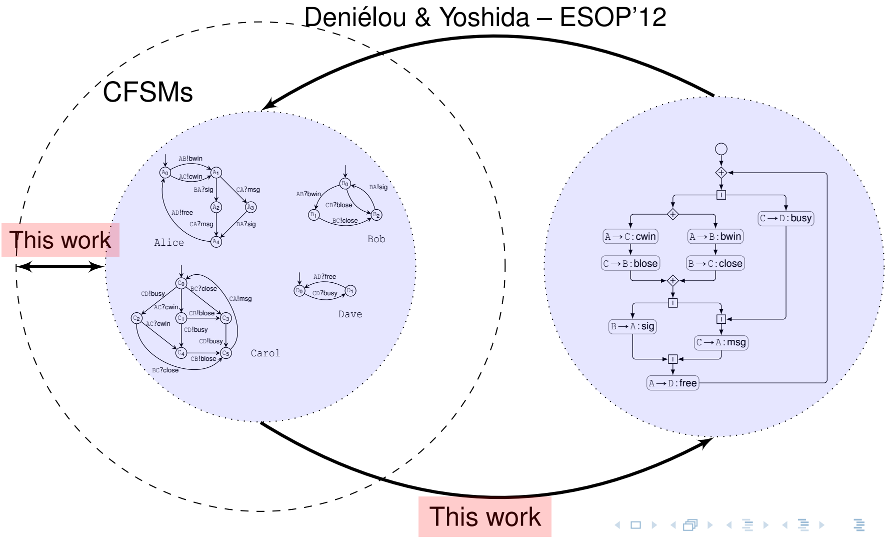



Deniélou & Yoshida – ESOP'12
CFSMs
This work
AB!bwin
AC!cwin
BA?sig
CA?msg
AD!free
Alice
AB?bwin
BA!sig
CB?blose
BC!close
Bob
CD!busy
BC?close
CA!msg
AC?cwin
CB!blose
CD!busy
BC?close
Carol
AD?free
CD?busy
Dave
C → D : busy
A → C : cwin
A → B : bwin
C → B : blose
B → C : close
B → A : sig
C → A : msg
A → D : free
This work

Objectives

Two main objectives:

- **Sound Condition for Safety:** generalised multiparty compatibility

  If $S = (M_1, \ldots, M_k)$ is *compatible* then S is “safe”, i.e., every sent message is eventually received and no deadlock.

- **Construction of a Global Graph:**

  If G is the global graph constructed from S, then

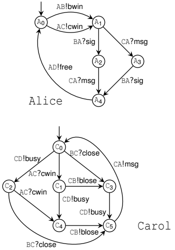
$$S = (M_1, \ldots, M_k) \equiv (G\downharpoonleft_1, \ldots, G\downharpoonleft_k)$$

The Plan

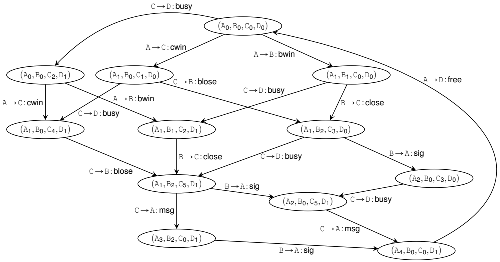
1. Build $\mathsf{TS}(S)$, the transition system of all *synchronous* executions
2. Check for safety on $\mathsf{TS}(S)$ to
   - ensure equivalence between original system and the projections of the choreography,
   - guarantee safety (no deadlock, no orphan message)
3. Build a choreography (global graph) from $\mathsf{TS}(S)$, relying on
   - the theory of regions, and
   - safe Petri nets.

1. Synchronous Transition System of CFSMs

Synchronous Transition System (TS(S))



Four Player Game (CFSMs)



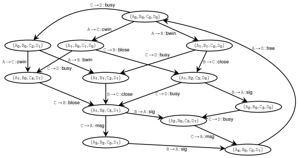
Synchronous Transition System (TS(S))

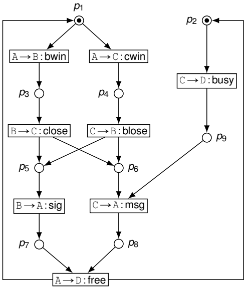
2. Check for Safety: *Generalised Multiparty Compatibility* (GMC)

1. Representability: ensures that TS contains enough information
   - Essentially: the projection of TS onto a participant must be branching bissimilar to the original machine.
2. Branching Property: each branching in TS is “well-formed”
   - it either corresponds to concurrent interactions, or
   - each participant eventually knows which branch was chosen.

3. Build a global graph

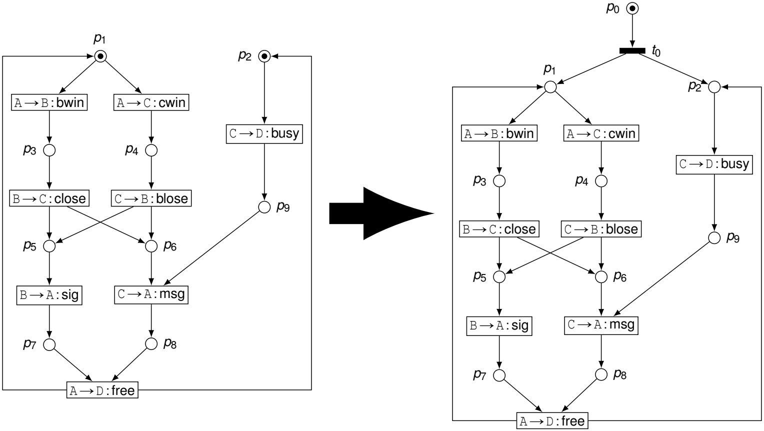
1: From TS to Petri Net





We use the work of Cortadella et al. (1998), based on the **theory of regions**, to derive a *safe* and *extended free-choice* Petri net from the Synchronous Transition System.

2: From Petri Net to One-source Petri Net



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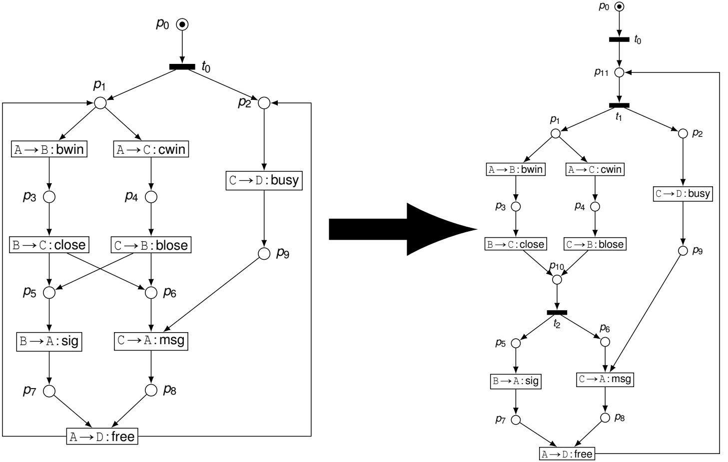
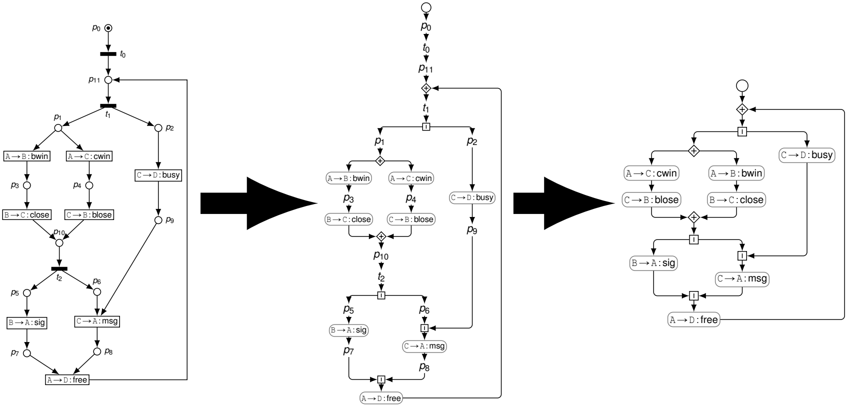
3: From One-source Petri Net to Joined Petri Net



4 & 5 : From Joined Petri Net to Global Graph



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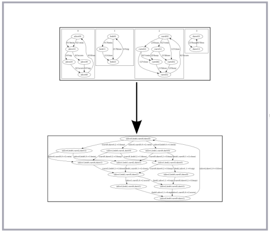
Prototype Implementation

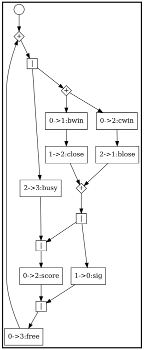
```
.outputs
.state graph
alice0 1 ! bwin alice1
alice0 2 ! cwin alice1
alice1 1 ? sig alice2
alice1 2 ! score alice3
alice2 2 ! score alice4
alice3 1 ? sig alice4
alice4 3 ! free alice0
.marking alice0
.end

.outputs
.state graph
bob0 0 ? bwin bob1
bob1 2 ! close bob2
bob0 2 ? blose bob2
bob2 0 ! sig bob0
.marking bob0
.end

.outputs
.state graph
carol0 1 ? close carol3
carol0 3 ! busy carol2
carol0 0 ? cwin carol1
carol1 3 ! busy carol4
carol1 1 ! blose carol3
carol2 1 ? close carol5
carol2 0 ? cwin carol4
carol3 3 ! busy carol5
carol4 1 ! blose carol5
carol5 0 ? score carol0
.marking carol0
.end

.outputs
.state graph
dave0 2 ? busy dave1
dave1 0 ? free dave0
.marking dave0
.end
```





https://bitbucket.org/julien-lange/gmc-synthesis

Conclusions and Future Work

- Summing up:
  - An effective way of checking properties of CFSMs, and whether one can construct a global graph from them.
  - An algorithm based on the theory of regions.
  - A CFSMs characterisation of well-formed *graphical global types*.
  - Tool(s):
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- Recent extension to support **Communicating Timed Automata**:
  - L. Bocchi, J. L., and N. Yoshida: Meeting Deadlines Together.
  - To appear in CONCUR'15
  - Preprint: `http://www.doc.ic.ac.uk/~jlange/cta/`

Thanks!

Any questions?

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