Distributed Diagnosis and Active Systems

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Decentralized = Distributed ?

- Sampath et al. - DX 1994, TAC 1995, TCST 1996: Diagnoser Approach (DA)
- Rozé - DX 1997: DA is intractable
- Baroni et al. - ECAI 1998, DX-AIJ 1999, TSMC 2000: *distributed* DESs + modular reconstruction (possibly coupled with a *distributed* architecture) = Active System Approach (ASA)

Distribution

is a means to

increase tractability

Lessons learnt

Both for a posteriori and monitoring-based diagnosis

- No global behavioral model needed
- A diagnosis problem can be decomposed into sub-problems

Decentralized = Distributed ?

- Pencolé - DX 2000: DA + ASA = *Decentralized* Diagnoser Approach (DeDA)
- Debouk, Lafortune, Teneketzis - DX+ JDEDS 2000: *Decentralized* Protocol Approach (DePA)

Decentralized = Distributed ?

- Pencolé, Cordier, Rozé - DX 2001: DA + ASA = Incremental *Decentralized* Diagnoser Approach (IDeDA)
- Lamperti, Zanella - DX 2001: *Distributed* Diagnosis (DiD)

Why distributed diagnosis?

- System,
- observation,
- diagnosis method,
- processing architecture

orthogonal concepts

- Distributed,
- modular,
- incremental,
- decentralized

distribution

Distributed system

Two orthogonal types of distribution:

- Structural
- Behavioral

Structural distribution

- The system is modeled as a net of components communicating with each other by means of connectors, and of the behaviors of components and connectors
- Both components and connectors can be modeled differently in distinct approaches (e.g. synchronous vs. asynchronous communication)

Distribution in modeling as the basis for distribution in diagnostic reasoning

Behavioral distribution

The behavior is modeled in terms of distinct physical views (e.g. mechanical, electrical, etc.) and of their reciprocal correspondences

Distributed vs. hierarchical modeling

Structural distribution is <u>not</u> Hierarchical topological modeling

Behavioral distribution is <u>not</u> Hierarchical behavioral modeling

concurrent reasoning ↓ (from Behavioral distribution)

sequential reasoning (structural and behavioral abstraction) ↓ (from Hierarchical behavioral modeling)

Concurrency

is an essential feature of

distribution

Combining the two system distributions

- The DES consists of a single component whose behavior is modeled by means of several physical views and of their correspondences
- The DES consists of several interconnected components, where the behavior of each component and connector is modeled by means of a single physical view

Combining the two system distributions

- The DES consists of several interconnected components, where the behavior of each component and connector is modeled by means of several views and there exist models for representing the correspondences of the views belonging to the same physical domain

Distributed observation

- How many observers? (Distribution of observers)
- What does an observer observe? (Distribution in space)
- When does an observer observe? (Distribution in time)

Observer

Event *e* is observed by observer ω if

(*e* can be physically detected by ω)

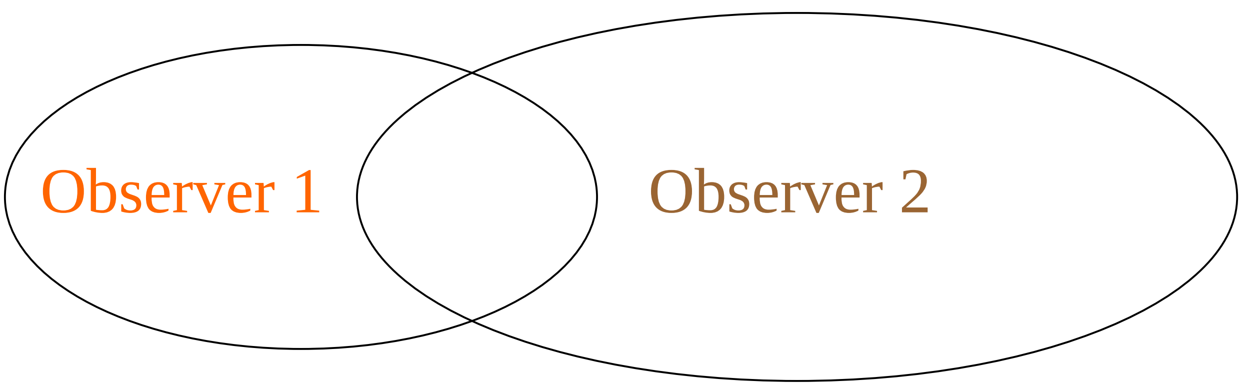
AND

(*e* is received by ω)

- Observer ω = {set of observable events of a given (sub)system}

How many observers for a (sub)system ?

- One
- Several
  - disjoint
  - (partially/completely) overlapping



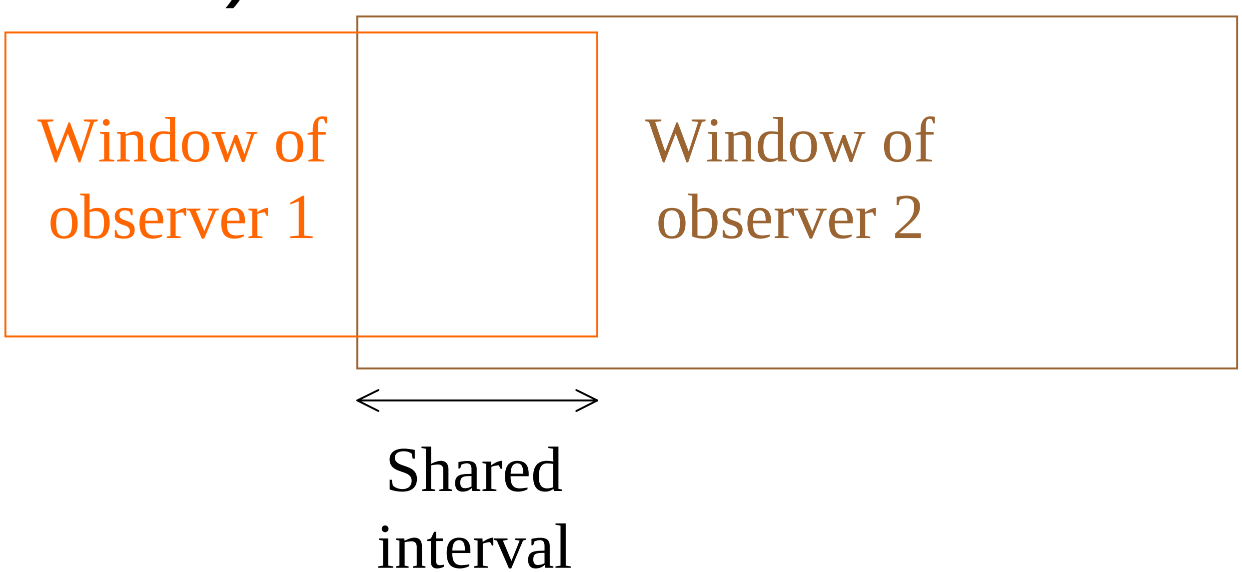
What does an observer observe?

- The whole system
- A set of components
- A set of components + connectors between each other ($\rightarrow$ a set of possibly disjoint clusters)
- A set of connectors

When does an observer observe?

Within a temporal window

- Not simultaneous with any other window
- (Partially/completely) simultaneous to (some/all) others



Multiple co-temporal observers (1)

If there exist several observers watching the same (sub)system within the same interval, the observation of such a (sub)system in that interval is the composition of several <u>views</u>, where each view is what is observed by a distinct observer; the views of overlapping observers may be overlapping

Multiple co-temporal observers (2)

It may be difficult to isolate the portion of observation inherent to a interval

Distributed observation vs. notion of observation

- Certain
- Uncertain
- Complex

The observation mess (1)

- One observer for the whole system, providing a certain observation of the whole system operation within one temporal window (non-distributed scenario)
- Several observers, each observing, without any uncertainty, the whole system simultaneously to all the others within one temporal window with no content overlap (e.g. observing different aspects, such as thermal, mechanical, electrical, etc.)

The observation mess (2)

- Several observers, each observing, without any uncertainty, and within distinct non-overlapping temporal windows, the whole system with no content overlap
- ...

Distributed method (1)

The diagnostic task is performed by means of the cooperation of several (sw) processing units, each carrying out a subtask (where independent subtasks can be run in parallel)

↓

goals:

- to cope with computational difficulty
- to increase scalability

Distributed method (2)

Subtasks can be identified

- Statically (i.e. independently of the specific problem, e.g. DePA)
- Dynamically (e.g. DeDA)

and scheduled

- adaptively
- non adaptively

Distributed architecture

The (hw) processing architecture consists of several nodes, whose interconnections can be

- Static (e.g. star architecture)
- Dynamic

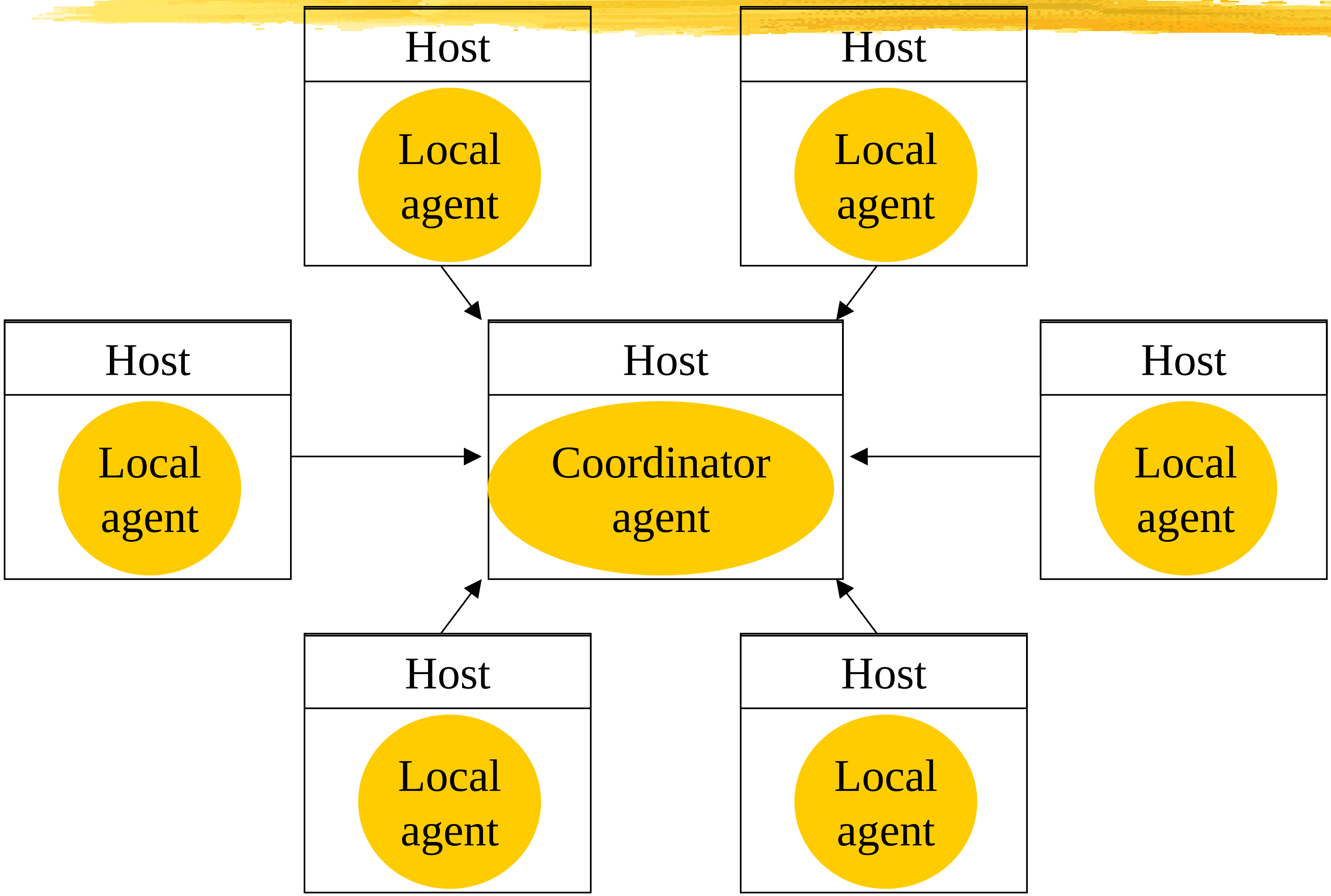
A node can host zero, one or more subtasks

DePA

- Non-distributed system
- Multiple overlapping simultaneous observers
- Non-distributed certain observation
- Statically distributed (monitoring-based diagnosis) method
- Statically distributed architecture

... *is it distributed diagnosis?*

DePA


Host
Local agent
Host
Local agent
Host
Local agent
Host
Coordinator agent
Host
Local agent
Host
Local agent
Host
Local agent

What is DD?

Concurrent reasoning on <u>sub</u>systems in order to produce diagnoses consistent with the whole system and the whole observation

Candidate diagnosis in DD

It may be inherent either to

- the whole system
- a subsystem (possibly a single component/connector)

but, in both cases, it is consistent with the whole system (i.e. all its models) and the whole observation, i.e. it is consistent with the whole diagnostic problem

ASA - System distribution

- Structural distribution (+ hierarchical topological modeling)
- No behavioral distribution

Models

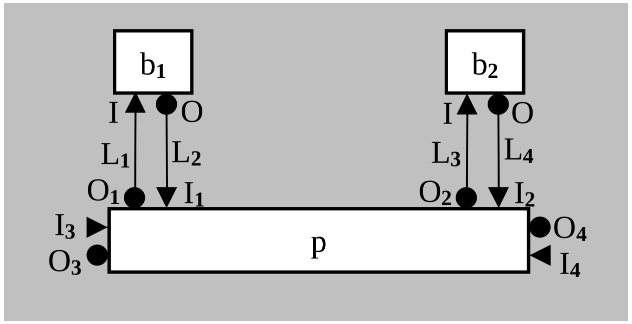
System

- Topology
- (Complete) behavior of each
  - Component
  - Link

Problem

- Ruler = what faults to diagnose
- Viewer = what is observable
- Observation = symptoms

Topology



ξ: system

p, b_1, b_2 : components

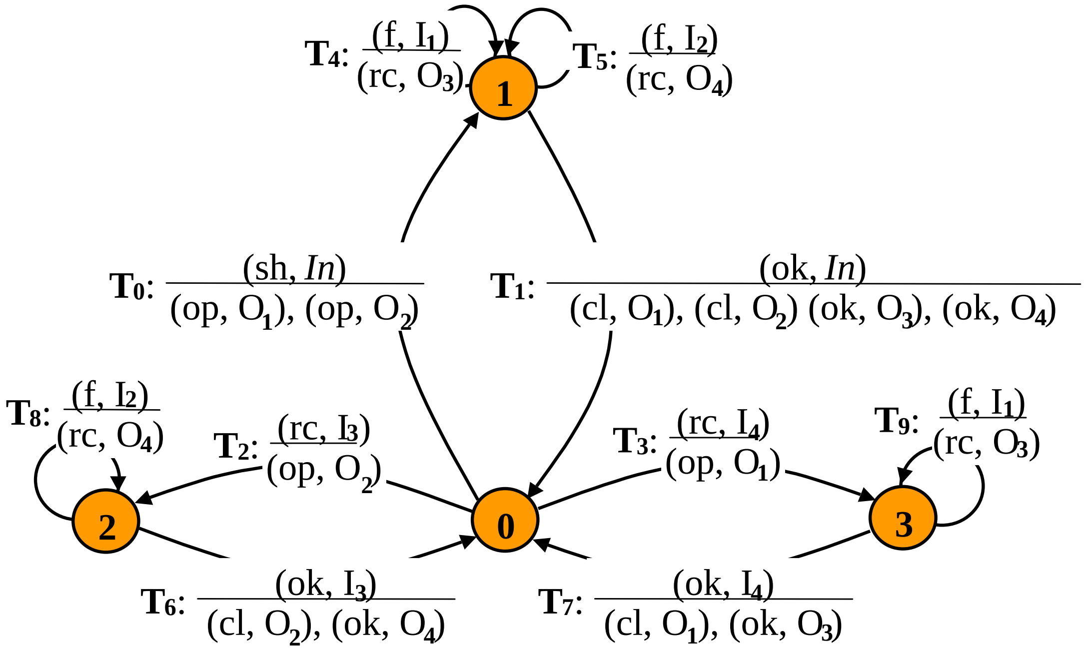
L_1 , L_2 , L_3 , L_4 : links

I_i, O_j + In : terminals

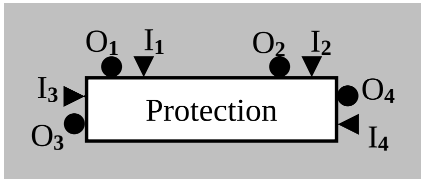
Links

- Capacity
- Management policy
- Saturation policy

Components

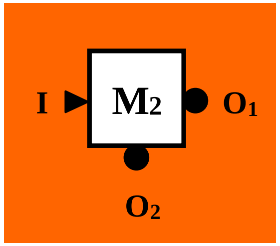


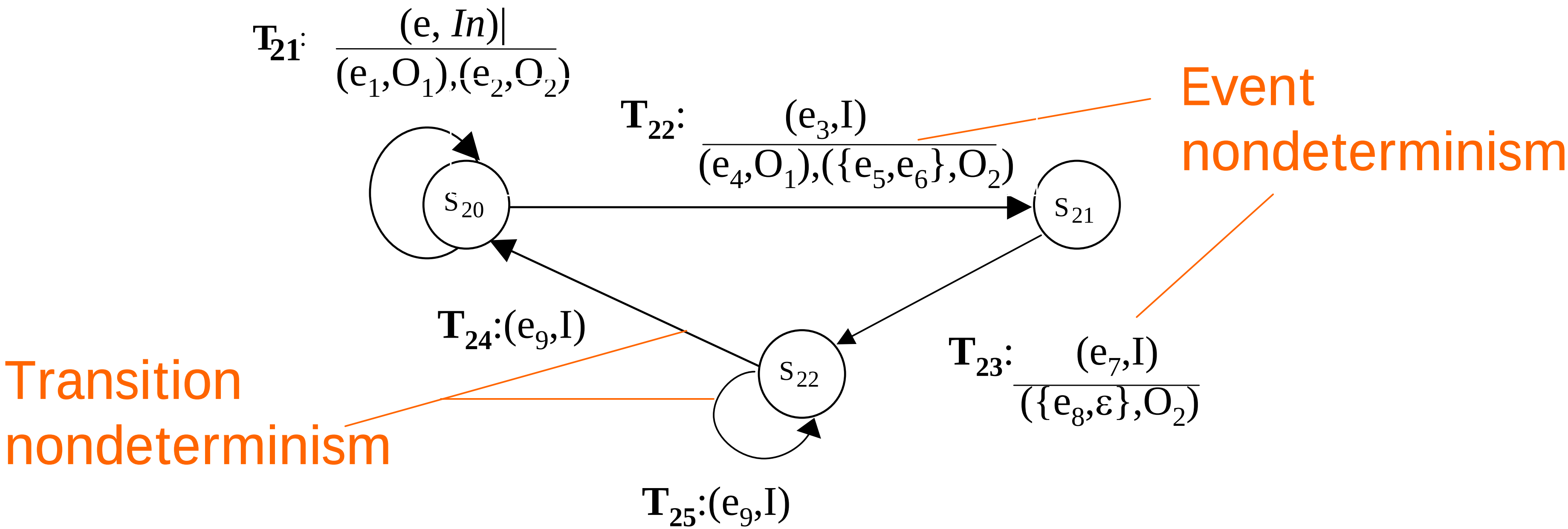
T4: (f, I1) / (rc, O3)
T5: (f, I2) / (rc, O4)
1
T0: (sh, In) / (op, O1), (op, O2)
T1: (ok, In) / (cl, O1), (cl, O2) (ok, O3), (ok, O4)
T8: (f, I2) / (rc, O4)
T2: (rc, I3) / (op, O2)
T3: (rc, I4) / (op, O1)
T9: (f, I1) / (rc, O3)
2
0
3
T6: (ok, I3) / (cl, O2), (ok, O4)
T7: (ok, I4) / (cl, O1), (ok, O3)



O1
I1
O2
I2
I3
O4
Protection
O3
I4

Uncertainty in component models





Ruler

It establishes which component transitions are reckoned as faulty, as well as the fault for each of them

Transition	***Fault***
$T_0(p)$	**S**
$T_3(b_1)$	**A**
$T_4(b_1)$	**B**
$T_3(b_2)$	**C**
$T_4(b_2)$	**D**

ASA - Observer distribution

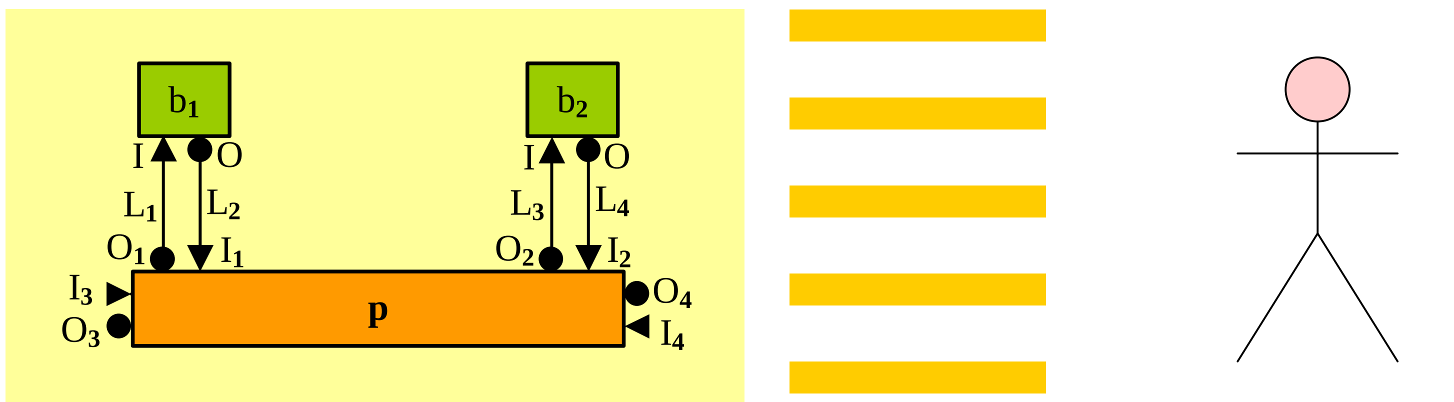
- Multiple simultaneous overlapping observers with overlapping uncertain views at DX 2001
- Single observer in recent works

Viewer

It establishes which component transitions are visible, as well as the observable label(s) for each of them

Transition	***Label***
$T_0(p)$	*sh*
$T_2(p)$	*l*
$T_3(p)$	*r*
$T_1(b_1)$	o_1
$T_2(b_1)$	c_1
$T_1(b_2)$	o_2
$T_2(b_2)$	c_2

Observation (1)

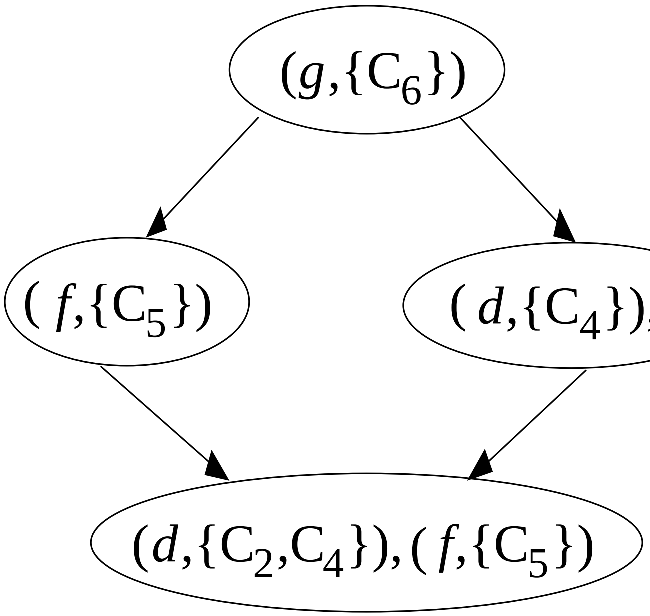


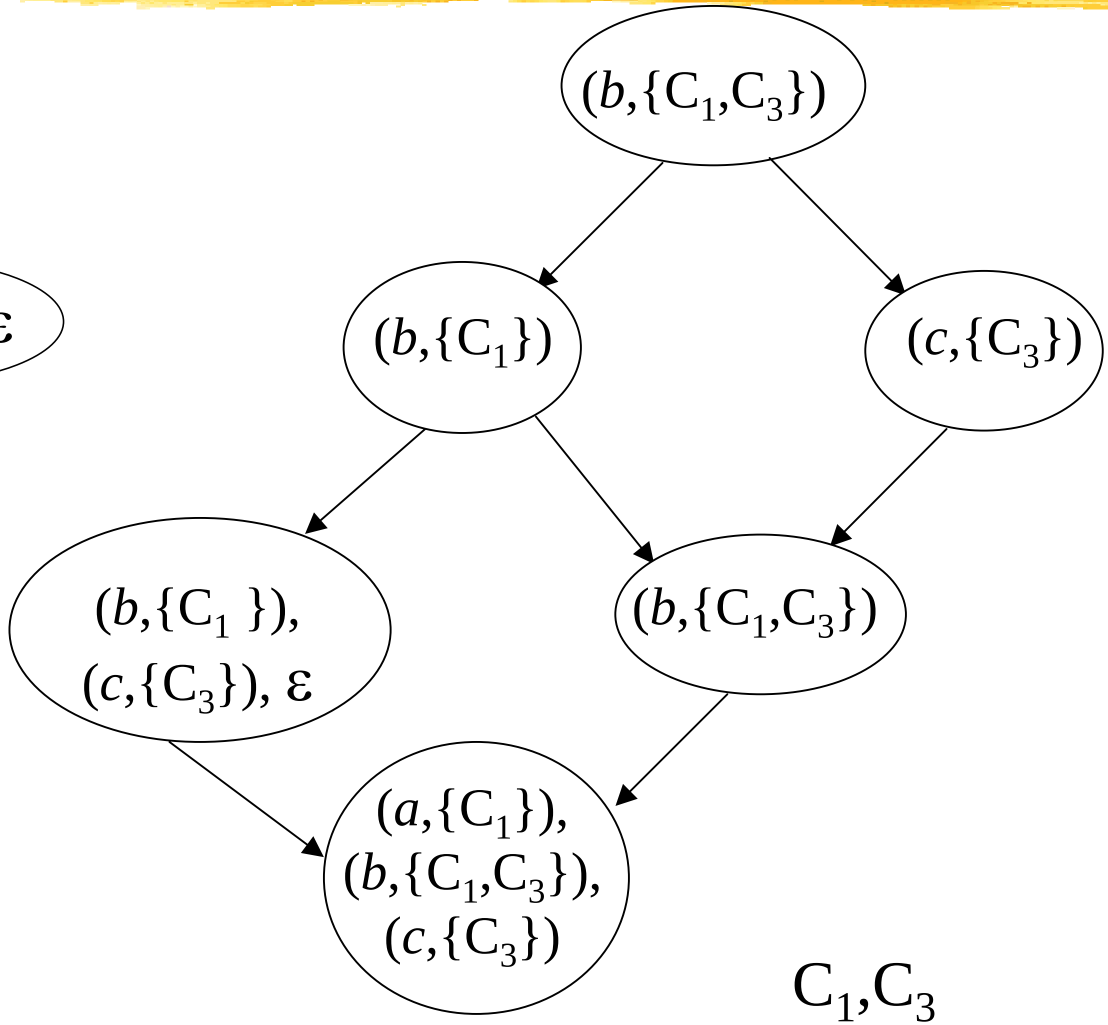
system (with links) channel(s) observer(s)

Observation (2)

- Each message consists of
  - a source content (sender component)
  - a logical content (observed label) +
  - a temporal content (position in the emission order)
- History reconstruction is based on the message emission order

Uncertain observation





C_2, C_4, C_5, C_6

C_1, C_3