Component signatures of networking process components require protocol and role declarations

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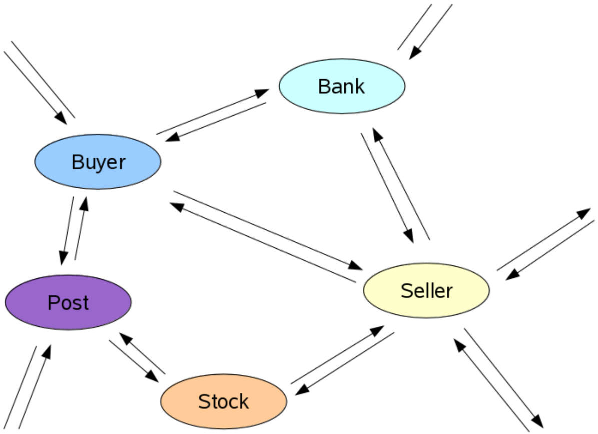
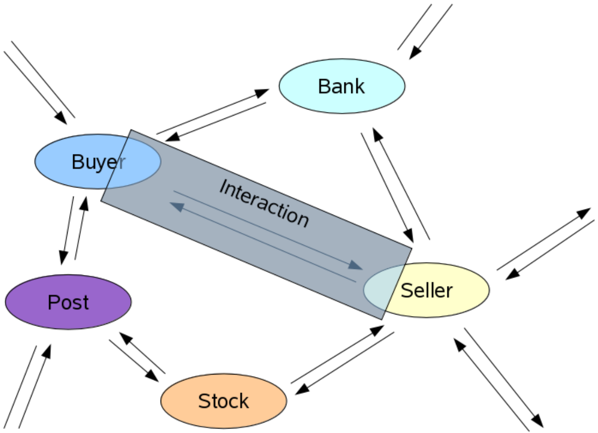
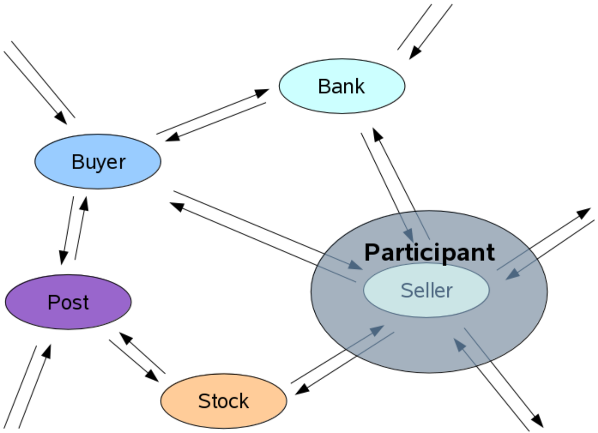
We are living in an open world of nondeterministic relations between systems



We are living in an open world of nondeterministic relations between systems: Focus on interactions



We are living in an open world of nondeterministic relations between systems: Focus on processes



Finite Systems - Formal Definition

A **finite system** is defined by a tuple $\mathcal{S} = (T, succ, Q, I, O, x, in, out, f)$.

- T is the enumerable set of time values starting with 0 such that $succ : T \to T$ is the invertible time successor function.
- Q, I and O are the finite sets of state values for the internal, input and output states $(x, in, out) : T \to (Q, I, O^\epsilon)$.
- $f = (f^{ext}, f^{int}) : I \times Q \to O^\epsilon \times Q$ is a function describing the time evolution or system operation triggered by an update of its input parameters and updating the internal and output state in one time step for each $t \in T$:

$$\begin{pmatrix} out(t+1) \\ x(t+1) \end{pmatrix} = \begin{pmatrix} f^{ext}(in(t), x(t)) \\ f^{int}(in(t), x(t)) \end{pmatrix}.$$

ϵ symbolizes the empty character and $I^\epsilon = I \cup \epsilon$ and $O^\epsilon = O \cup \epsilon$.
The n-fold application of $succ$ is written as $t +_{\mathcal{S}} n := succ^n_{\mathcal{S}}(t)$

Projection of a System

Def.: A tupel $\mathcal{T} = (T, succ, Q_{\mathcal{T}}, I_{\mathcal{T}}, O_{\mathcal{T}}, x_{\mathcal{T}}, in_{\mathcal{T}}, out_{\mathcal{T}}, \Delta_{\mathcal{T}})$ is a **projection** of a system $\mathcal{S}$ if

- $Q_{\mathcal{T}} \subseteq Q_{\mathcal{S}}$, $I_{\mathcal{T}} \subseteq I_{\mathcal{S}}$, $O_{\mathcal{T}} \subseteq O_{\mathcal{S}}$ and
- $\Delta_{\mathcal{T}} \subseteq Q_{\mathcal{T}} \times Q_{\mathcal{T}} \times I^{\epsilon}_{\mathcal{T}} \times O^{\epsilon}_{\mathcal{T}}$ and
- a projection function $\pi = (\pi_Q, \pi_I, \pi_O) : Q_{\mathcal{S}} \times I^{\epsilon}_{\mathcal{S}} \times O^{\epsilon}_{\mathcal{S}} \rightarrow Q_{\mathcal{S}} \times I^{\epsilon}_{\mathcal{S}} \times O^{\epsilon}_{\mathcal{S}}$ with $\pi \circ \pi = \pi$ exists

such that $\delta \in \Delta_{\mathcal{T}}$ iff there is a point in time $t \geq 0$ in a sequence such that $\delta = (\pi_Q(x(t)), \pi_Q(x(t+1)), \pi_I(in(t)), \pi_O(out(t+1)))$.

Nondeterministic Finite I/O-Automata (Transducer)

Def.: A **nondeterministic finite I/O automaton (NFIOA)** is defined by a tuple $\mathcal{A} = (Q, I, O, q_0, Acc, \Delta)$.

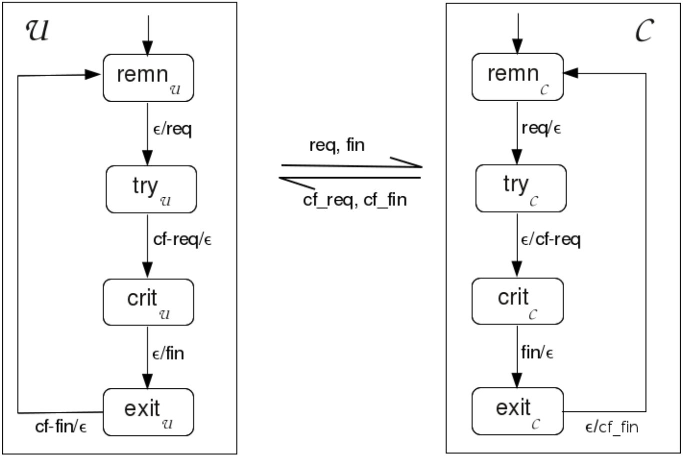
- Q is the non-empty finite set of state values,
- I and O are the (possible empty) finite input and output alphabets,
- q_0 is the initial state value,
- Acc is the acceptance component (e.g. a finite set of states for finite input sequences) and
- $\Delta \subseteq Q \times Q \times I^\epsilon \times O^\epsilon$ is the transition relation.

Remark 1: For finite input sequences an NFIOA defines an I/O-mapping $I^{\epsilon*} \to O^{\epsilon*}$.

Remark 2: The transitions are anonymously defined, i.e. they are not named.

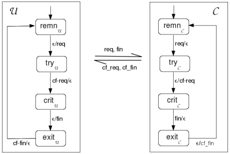
Def.: An NFIOA $\mathcal{A} = (Q_\mathcal{A}, I_\mathcal{A}, O_\mathcal{A}, q_0, Acc, \Delta)$ **specifies** the projection $\mathcal{T}$ of a system $\mathcal{S}$, if $Q_\mathcal{A} = Q_\mathcal{T}$, $I_\mathcal{A} = I_\mathcal{T}$, $O_\mathcal{A} = O_\mathcal{T}$, $q_0 = x_\mathcal{T}(0)$ and $\Delta_\mathcal{A} = \Delta_\mathcal{T}$.

Example: the Protocol of Mutual Exclusion

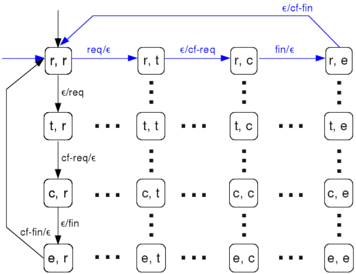


Causal Relation between the Output and the Input of different Systems - Channel Based Restriction (chbr)

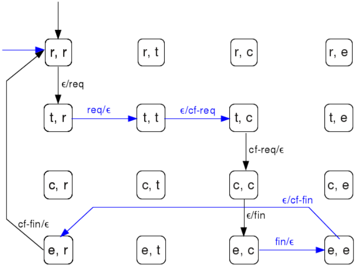
Example of the Protocol of Mutual Exclusion

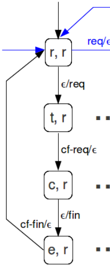


Weakly synchronized product



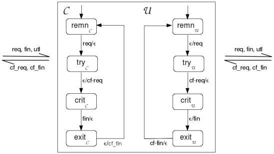
Channel based restricted product



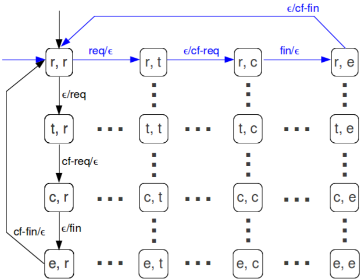


Causal Relation between the Input and Output of the same System - Condition Based Restriction (cobr)

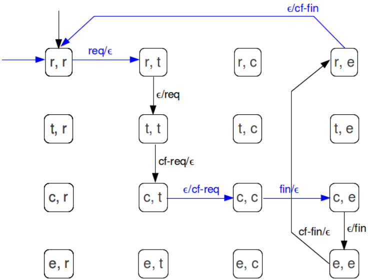
Example "Man in the Middle" in the Protocol of Mutual Exclusion



Weakly synchronized product



Condition based restricted product



Protocols

Def.: A chbr-automaton is called **well formed** if for every channel mediated transition which sends a character (different from ϵ) there exists an induced transition to process it.

Def.: A well formed chbr-automaton is called **consistent** if for each reachable state value either the acceptance condition is met or there is at least one continuation such that the acceptance condition can be met.

Def.: A **protocol** is a chbr-product automaton with no open input or output components. The individual factor automata are called **roles**.

Summary

- Network-like interactions are not deterministic, but are nondeterministic. The actions are not determined by the interactions!
- NFIOAs can be interpreted as specifications of the transition behavior of system projections.
- The causal relation between the input and output of different finite systems is represented by channel based restrictions.
- The causal relation between the input and output of the same finite system is represented by condition based restrictions.
- Components with intentional deterministic interfaces can be described by their operations. Eventual undesired nondeterminism is declared as exceptional.
- Components with intentional nondeterministic interfaces, i.e. containing processes, need roles and protocols in their signature.

Literature

J. Reich (2012), Processes, Roles and Their Interactions, in *Johannes Reich and Bernd Finkbeiner:* Proceedings Second International Workshop on Interactions, Games and Protocols (IWIGP 2012), Tallinn, Estonia, 25th March 2012, Electronic Proceedings in Theoretical Computer Science 78, pp. 24–38.

Thank You!

Any questions?

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