"Ecole IRISA" : distributed algorithms and models
Course 2 : true-concurrency models

C. Jard, October 2006

- 2.1 Message sequence charts
- 2.2 Basic pomsets
- 2.3 High-level MSC
- 2.4 Associated formal languages
- 2.5 Behavioral semantics
- 2.6 Petri nets

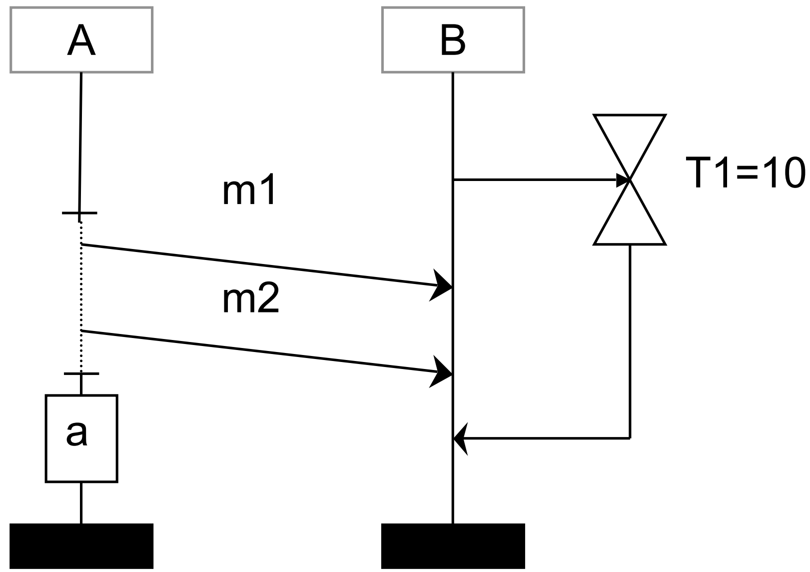
2.1 The MSC example "Message Sequence Charts"

Chronograms are a natural way to represent message exchanges in distributed systems

- Historically, MSC were a way to draw the execution traces of distributed programs specified in
- Studied by the ITU (GE10) till 1992 (the current « basic MSC »)
- Extensions and semantics: the Z.120 standard (the MSC'96 with composition features)
- MSC'2000 : introduction of data. Towards a specification/programmation language?!

bMSC: asynchronous message passing

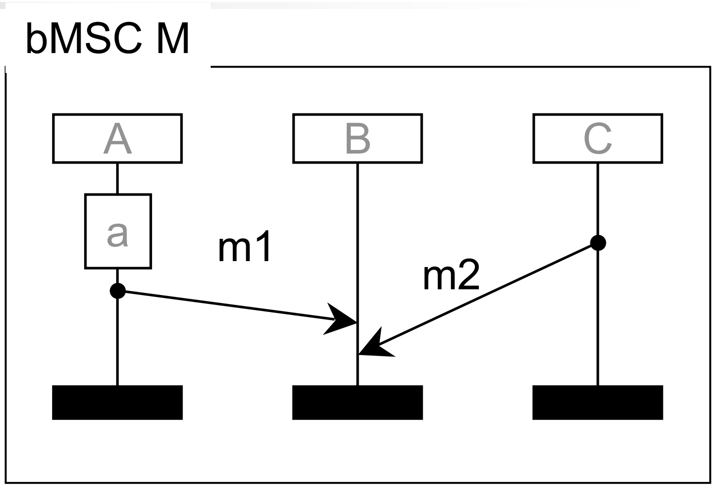
- Vertical representation of the instances
- Emission
- Reception
- Timer
- Co-region
- Atomic internal actions

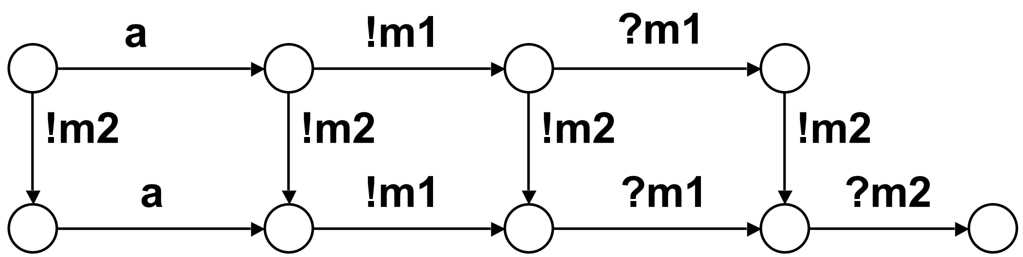


2.2 bMSC: labelled partial order (pomset)

$M = < E, \leq, I, \phi >$

- E : events
- $\leq$: causal order
- I : instances
- $\phi \subseteq E \times I$: localisation

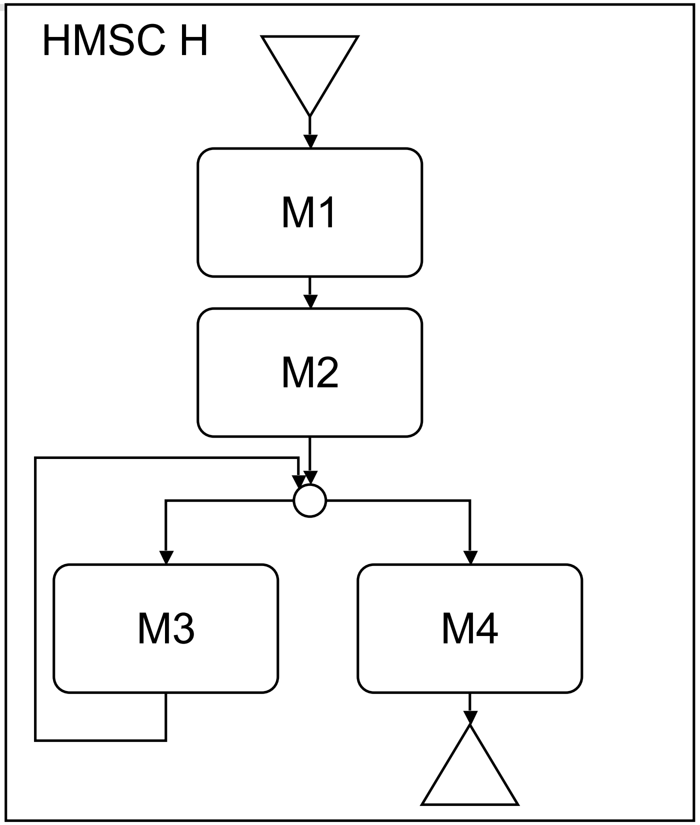




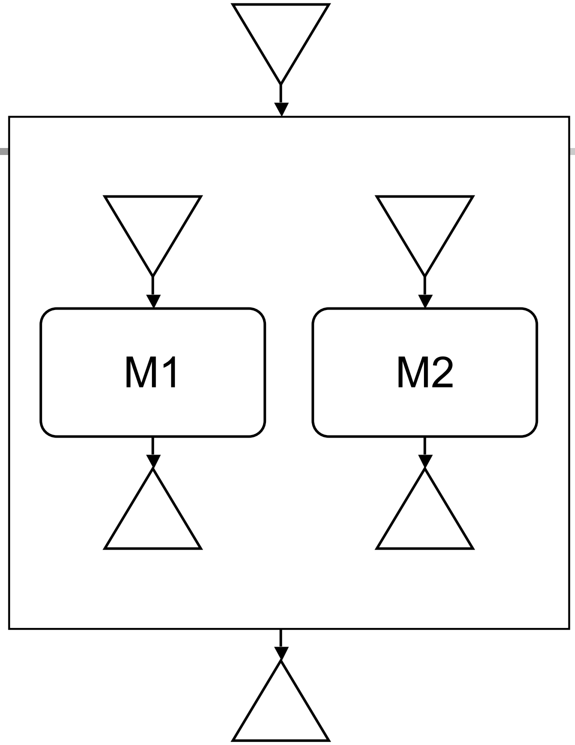
L(M) = { Prefixes of words of E* consistent with the causal order }

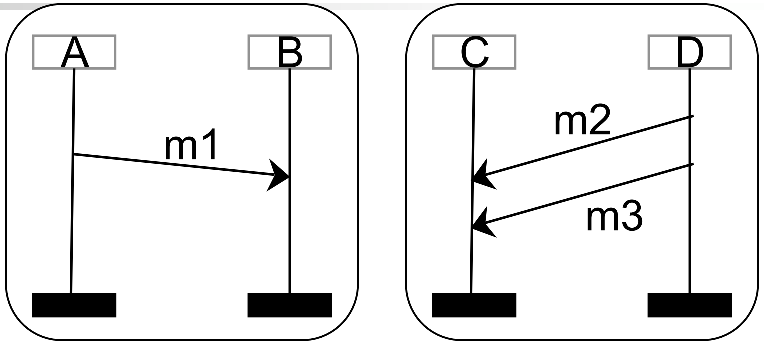
2.3 HMSCs: "High-level" Message Sequence Charts

- Begin and End nodes
- Sequential and parallel compositions
- References to other HMSCs
- Connectors (choices and loops)



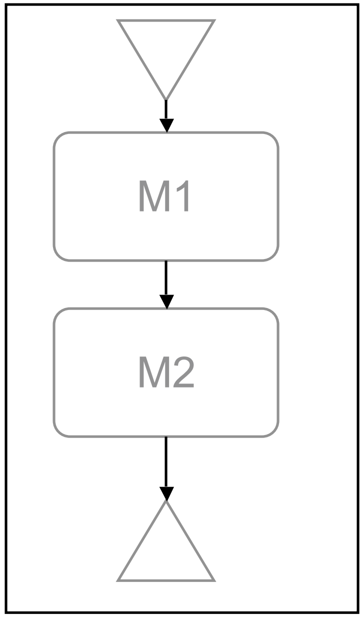
Parallel composition



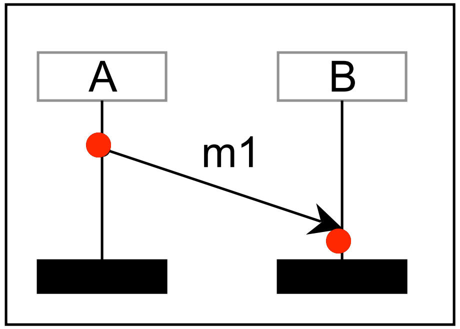


- Simple union when instances are disjoint
- else requires the computation of the interleavings (is not primitive)

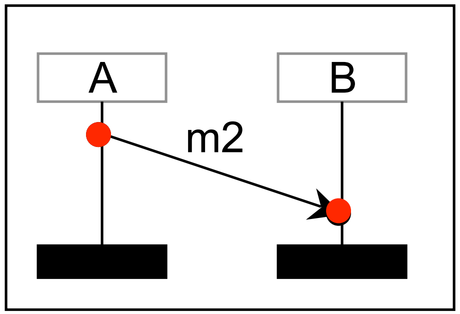
(Weak) sequential composition

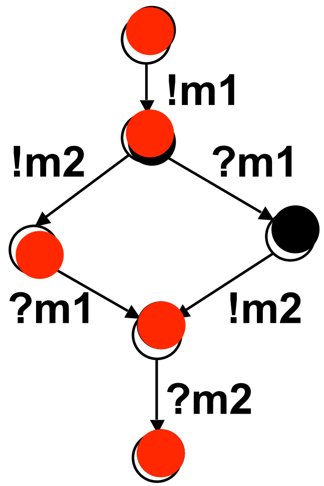


MSC M1

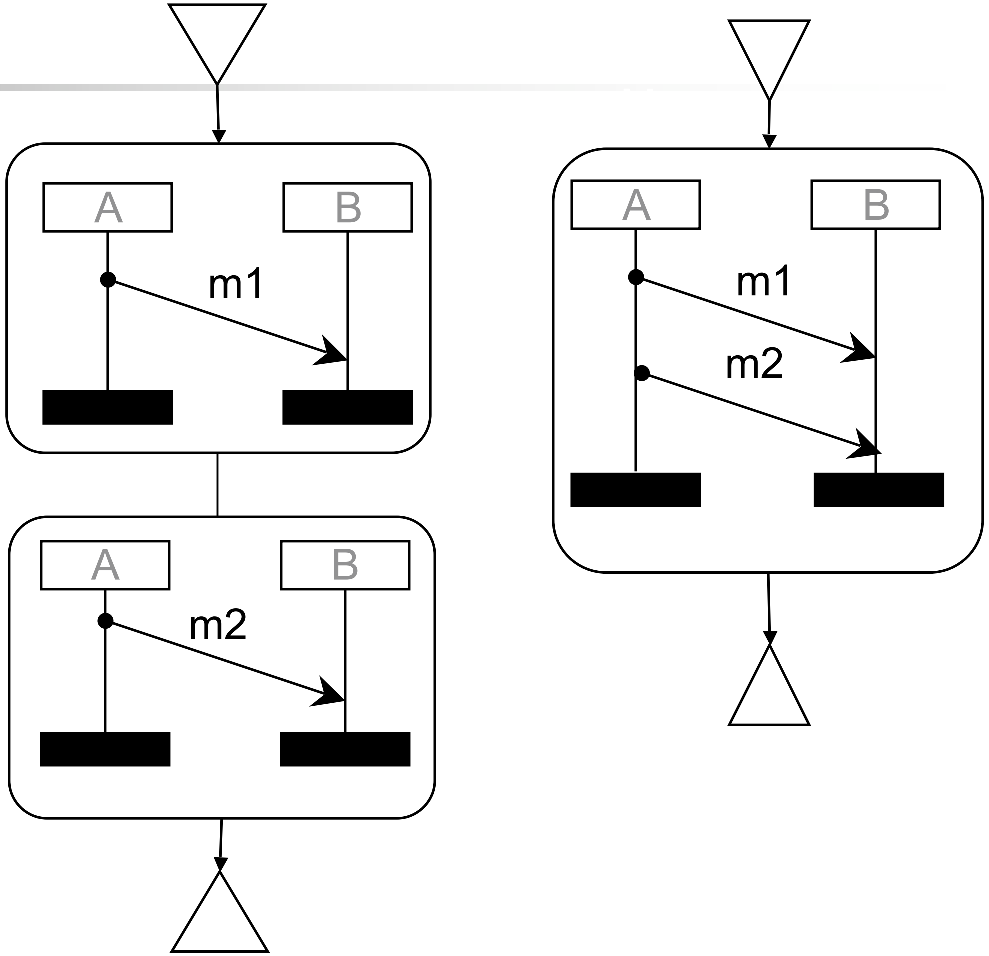


MSC M2

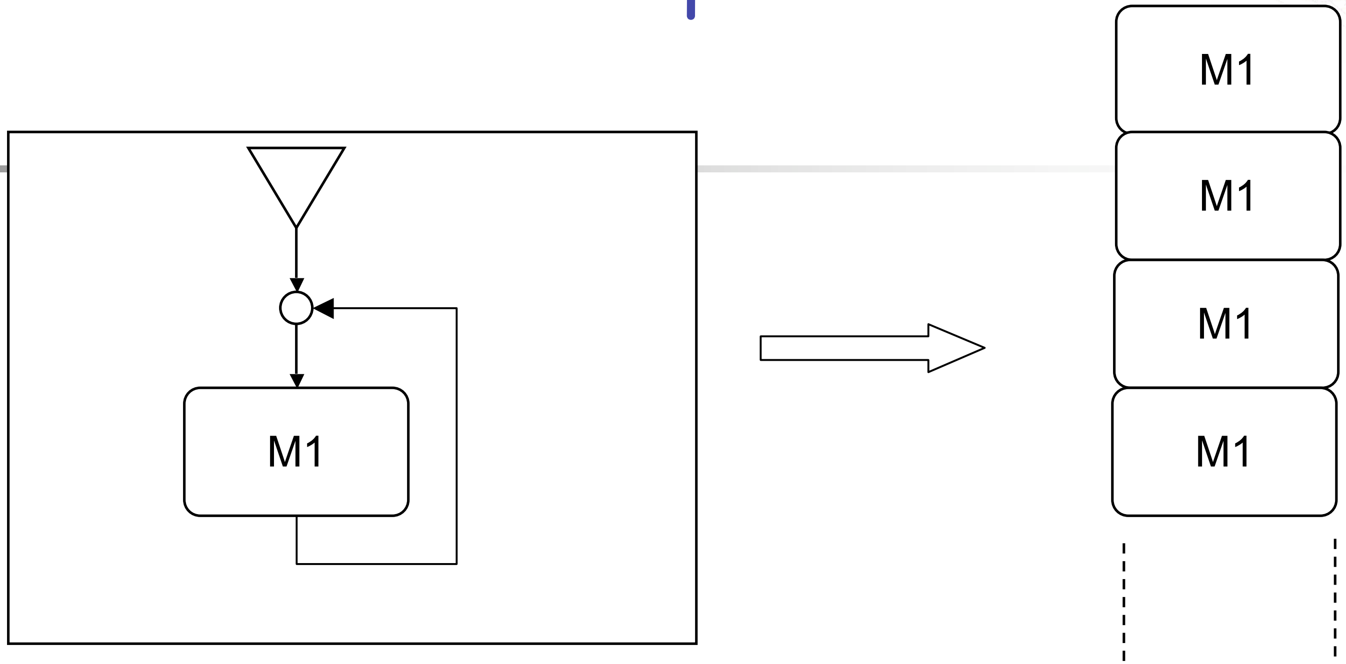




- Decomposing into bMSCs is not relevant (canonical form?)
- Gives a strong theoretical expressive power, despite the communication-closed form of the bMSCs

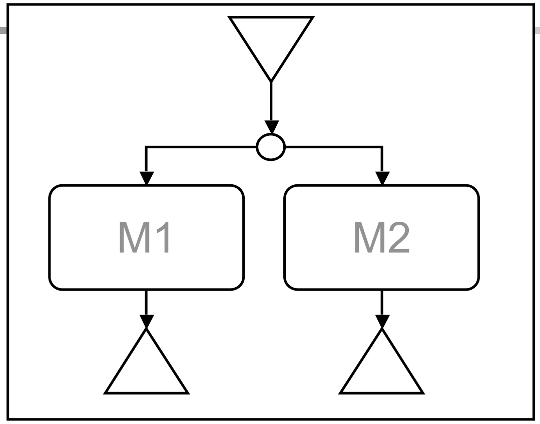


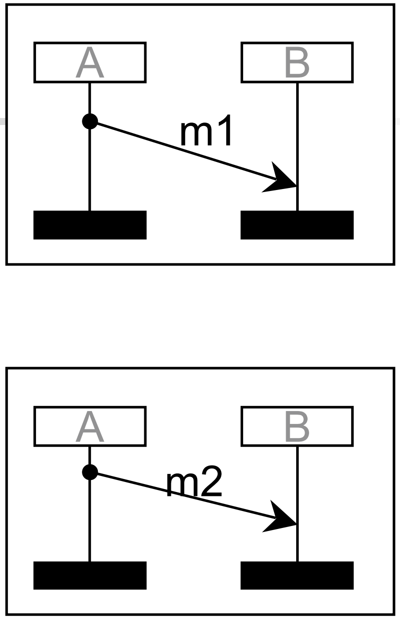
Loops

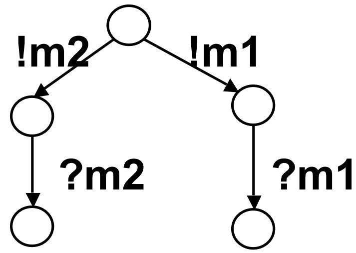


- Unbounded behaviours
- One alternative is a synchronizing sequential composition, which restricts to regular behaviours. Immediate connection to existing model-checking tools, but is very limited in practice.

Choice



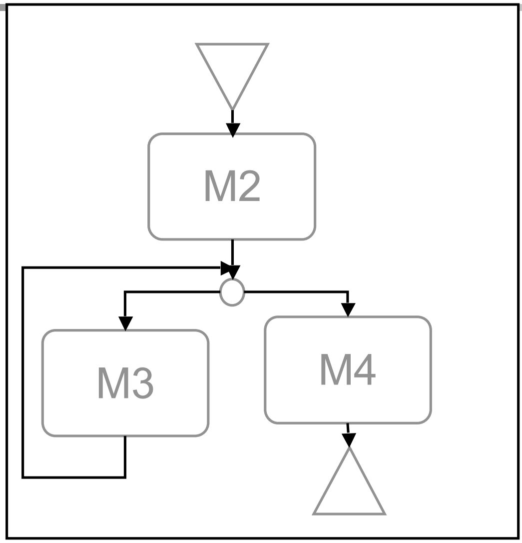


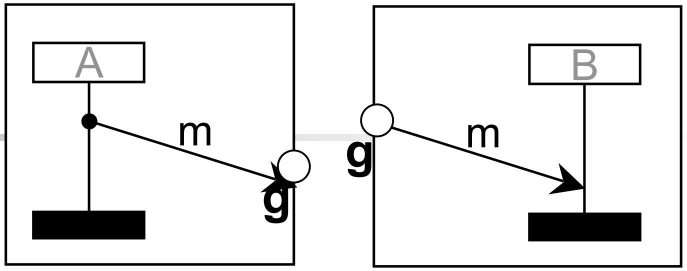


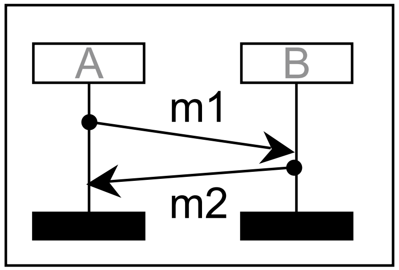
- Exclusive choice
- Problem of non-local choices
- Different interpretations of non-determinism are possible (delayed choices)

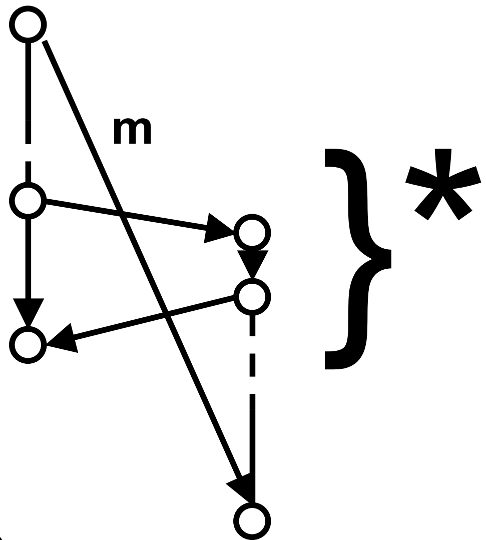
Ports

HMSC H



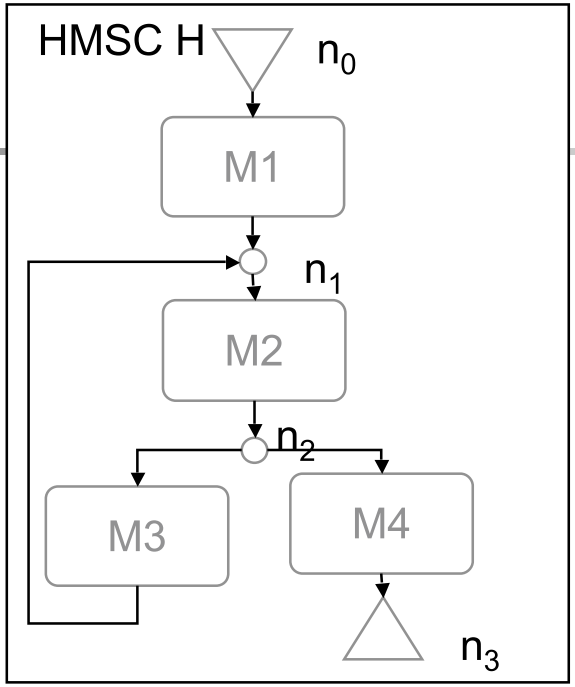






- (Too?) expressive
- H cannot be reconstructed without ports
- Nunerous undecidable questions (e.g. boundedness) -> communication closedness is a good compromise

2.4 Languages



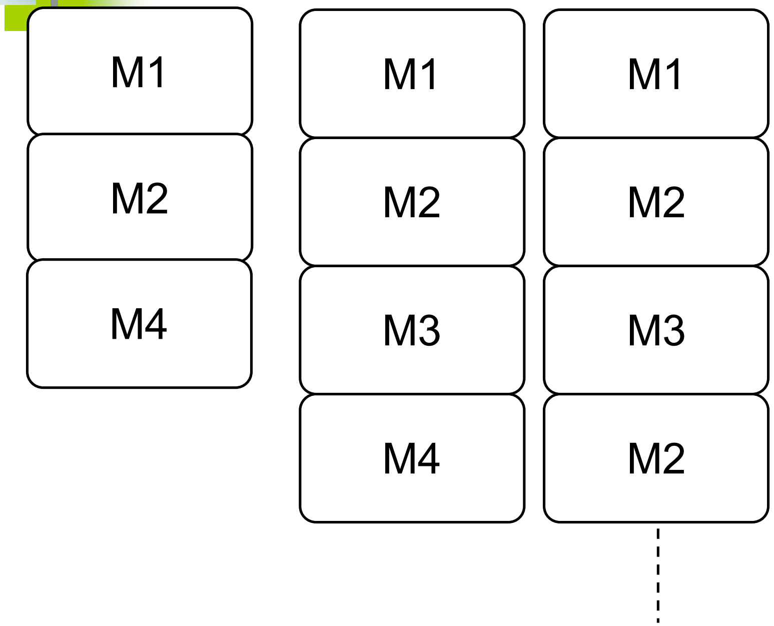
HMSC:

$H = < N, \rightarrow, M, l, n_0 >$

- N : nodes
- $\rightarrow \subseteq N^2$: connections
- M : bMSCs
- $l \subseteq N^2 \times M$: labelling
- n_0 : initial node

Paths:

- $Paths(H) = \{ p = n_1 . . . n_k \mid i < j, (n_i, n_j) \in \rightarrow \}$



Partial orders associated with paths :

$$\forall p = n_1..n_k \in Paths(H),$$

$$O_p = l(n_1,n_2) \circ l(n_2,n_3) \circ \ldots \circ l(n_{k-1},n_k)$$

Language of a HMSC H :

$$L(H) = \bigcup_{p \in Paths(H)} L(O_p)$$

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Let 2 HMSCs H1 and H2, R a rational subset.
Questions :

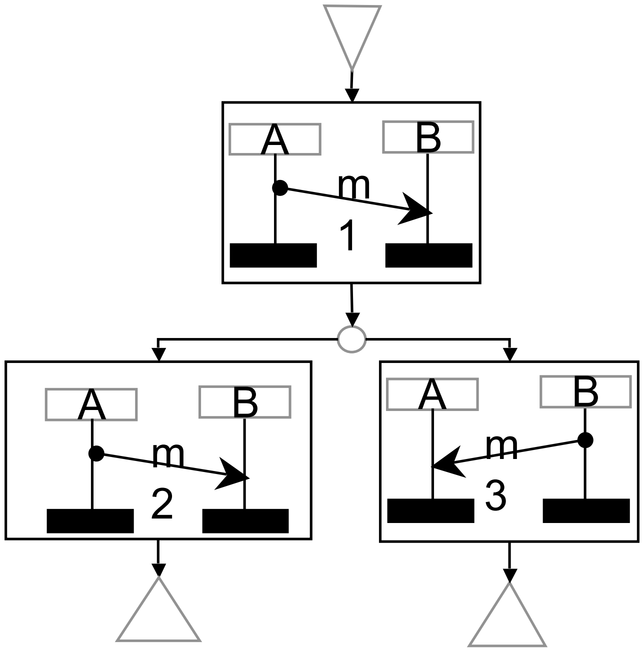
$$L(H1) = L(H2)$$
$$L(H1) \subseteq L(H2)$$
$$R \subseteq L(H2)$$
$$L(H1) \subseteq R$$
$$L(H1) = R$$
$$L(H1)\ rational$$

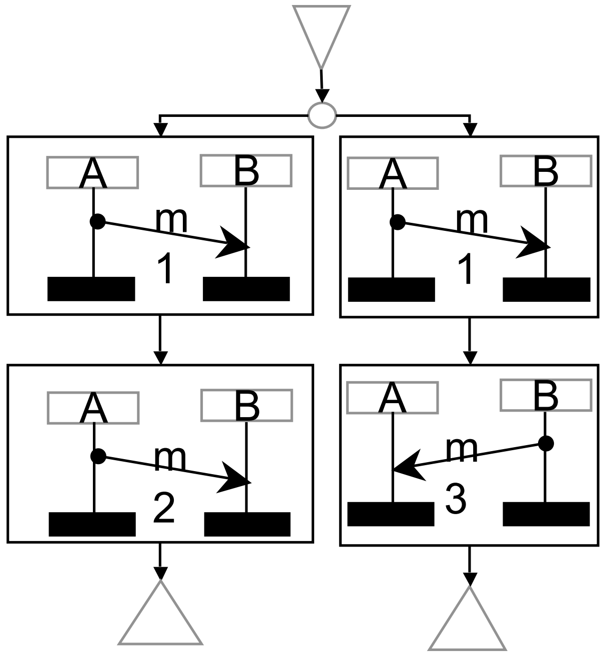
are undecidable (reduction to the Post correspondance problem)

2.5 Behavioral semantics

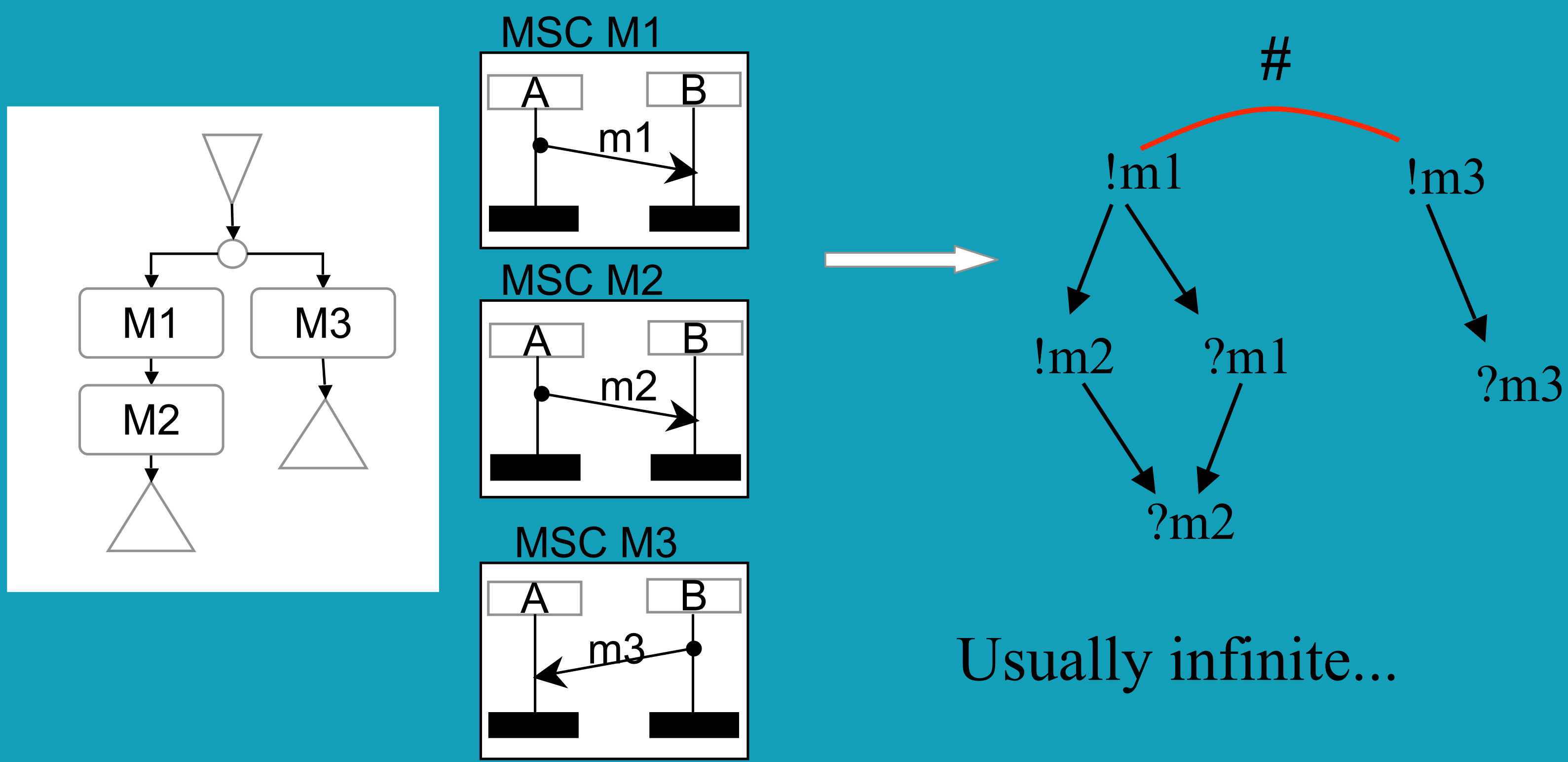
- Official semantics given in terms of process algebra BPAε [Mauw, Reniers 94-97, Gehrke, Huhn, Rensik, Wehrheim 98, Kosiuczenko 00] : sequential interleaved approach
- Partial order semantics:
  - Petri net attempt [Grabowski 98, Heymer 98-00] (Problem with the order of receptions)
  - Family of orders generated by paths [Heymer, Katoen, Lambert 98] (loose the branching information)
  - Event structures and its finite representation using graph grammars [Hélouët, Jard, Caillaud 98-01]

Branching information



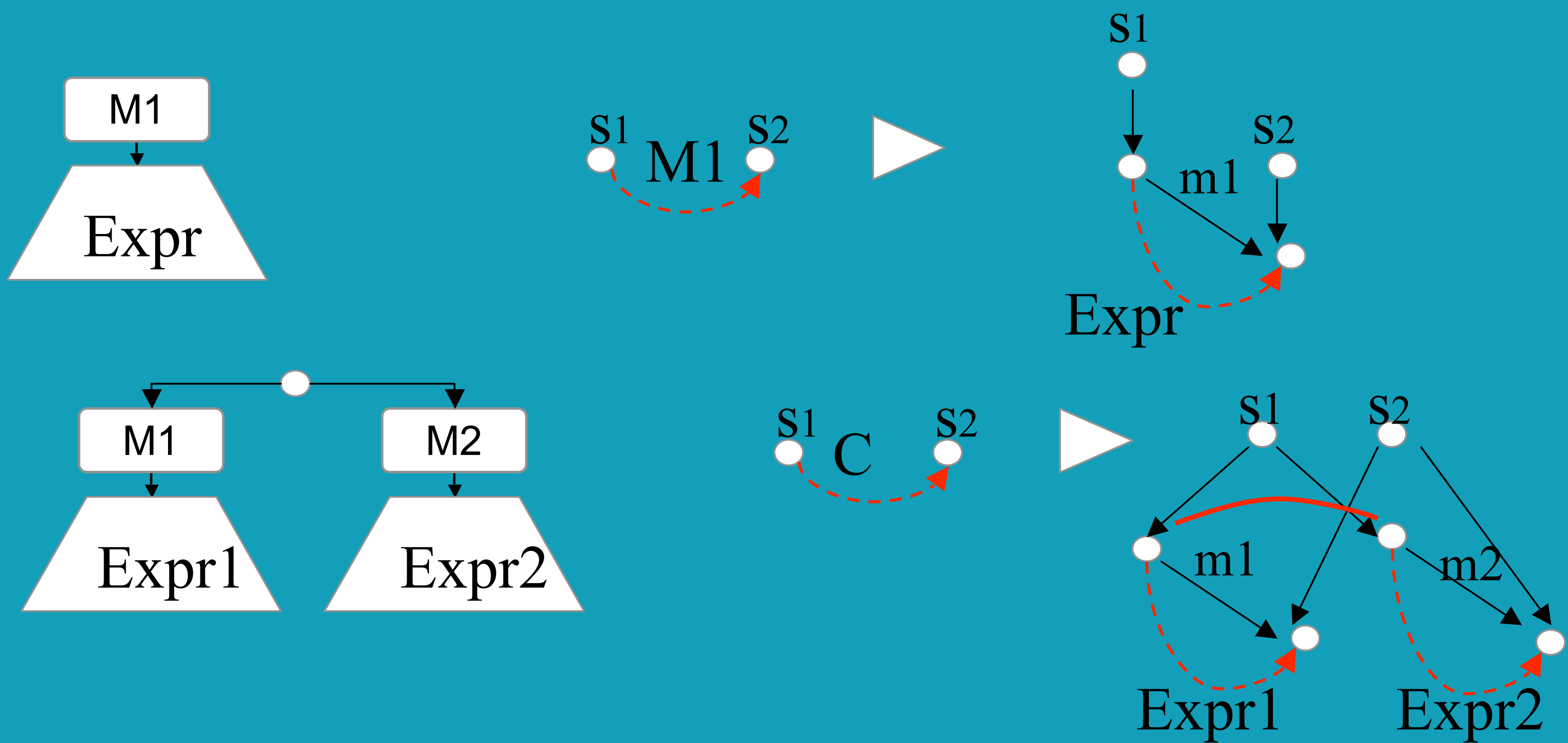


Events structures



Usually infinite...

Grammar construction

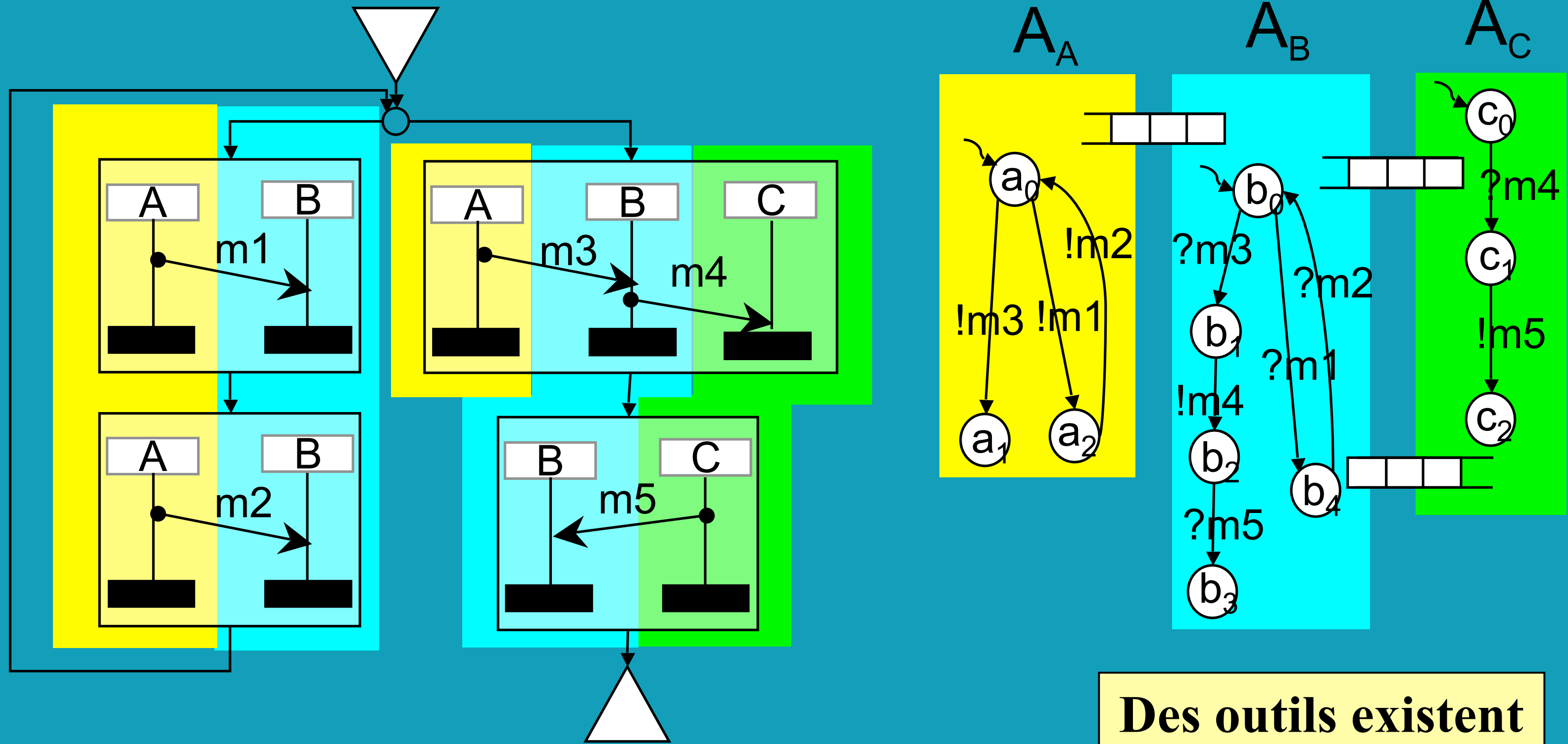


- ***L'équivalence de deux HMSC, définie comme l'isomorphisme de leur structure d'événement est décidable (sur les grammaires)***
- ***La mise en forme normale des grammaires engendre un simulateur efficace des HMSC***

Divergence

- ***Il y a divergence lorsqu'un groupe d'instances peut évoluer indéfiniment sans se synchroniser avec le reste des instances (e.g. débordement de messages)***
- ***La divergence est décidable : il suffit de répérer un cycle dont le motif ne contient pas de synchronisations (construction du graphe des communications) [Alur, Yannakakis 99]***
- ***Un MSC non divergent peut être codé par un système de transitions de taille bornée [Morin 01]***
- ***Mais cette classe exige entre autres que tout message envoyé dans une boucle soit acquitté***

Synthèse de processus communicants



Des outils existent

- ***Simple projection : problème de la caractérisation de la classe de MSC dont les comportements sont préservés (choix non local, ordre des réceptions, …)***
- ***[Yamanaka 96, Mansurov 99-00, Khendec 98, …]***

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2.6 Petri Nets

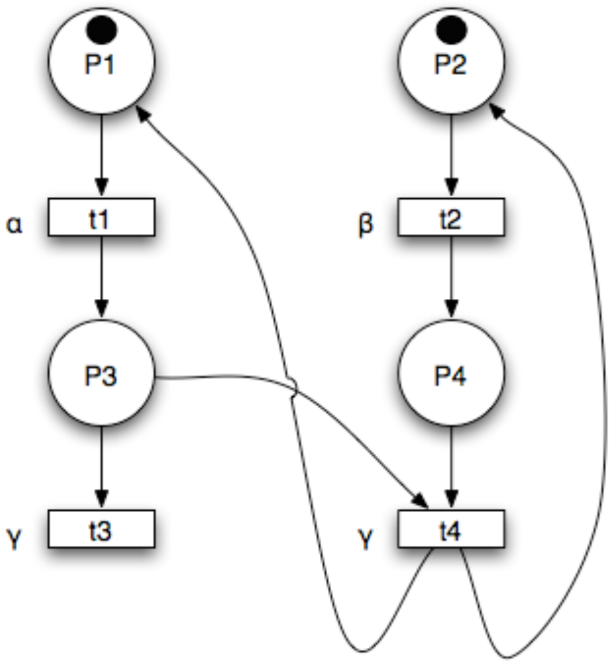
$N=(P,T,\to,M_0,\Sigma,\lambda)$

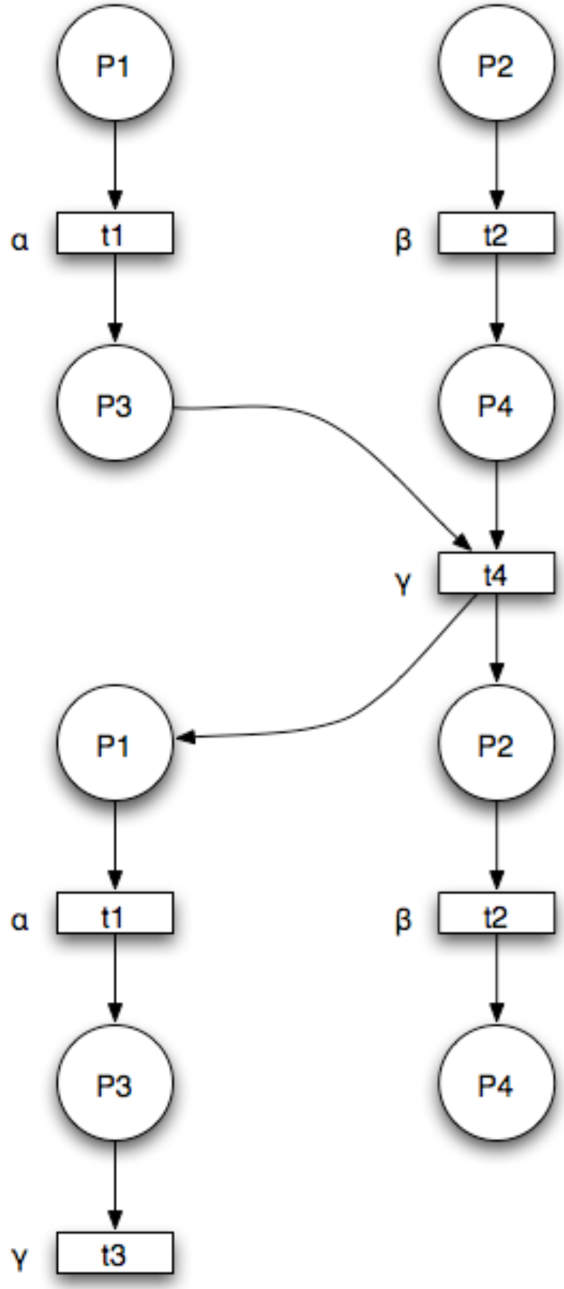
- P and T disjoint finite sets of places and transitions, $\to$ flow relation in $(P\times T \cup T\times P)$
- $\lambda : T \to \Sigma$ labeling of transitions (alarm names)
- $\leq$ et $<$ are the transitive closures of $\to$
- For $x \in P \cup T$, preset ${}^{\circ}x = \{y \mid y \to x\}$,
  postset $x^{\circ} = \{y \mid x \to y\}$
- A marking is a multiset $M : P \to \{0,1,2, \ldots\}$
- M_0 : initial marking
- $t \in T$, t is firable in the marking M iff ${}^{\circ}t \leq M$
- If t fires, $M := (M - {}^{\circ}t) + t^{\circ}$

Processes

- Events are transitions occurrences : E ($\perp \in E$)
- $e \in E$, $e = ({}^{\circ}e, \tau_e)$, $\tau_e \in T$, ${}^{\circ}e = \{({}^{\circ}b, place(b))\}$
- ${}^{\circ}b$ is the event that has created a token in place(b)
- b° is the event that consumes a token in place(b)
- $Place(B) = \{| \ place(b), b \in B \ |\}$
- $\uparrow E = \cup_{e \in E} e^{\circ} \setminus \cup_{e \in E} {}^{\circ}e$
- The set X of all processes is defined inductively by:
  - $\emptyset \in X$
  - For all process $E \in X$, for all transition t, and for all set $B \subseteq \uparrow E$ such that $Place(B) = {}^{\circ}t$, $E \cup \{e\} \in X$, where $e = (B, t)$

Example of process





Unfolding: superimposition of all processes

Consider the union U of processes

Process extraction:

- [e]={e'|e'≤e} (The unfolding is itself a PN)
- E⊆U is a process iff:
  - [E]=E (E is causally closed)
  - ∀ e,e'∈E °e∩e'°=∅ (E is conflict free)