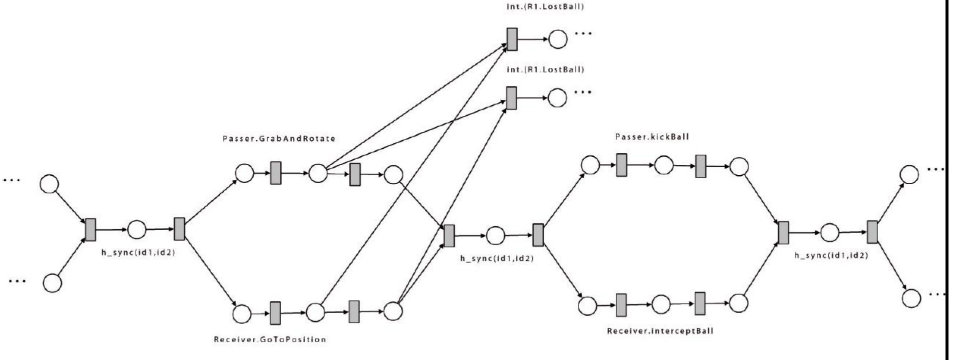
Embedded Systems 7

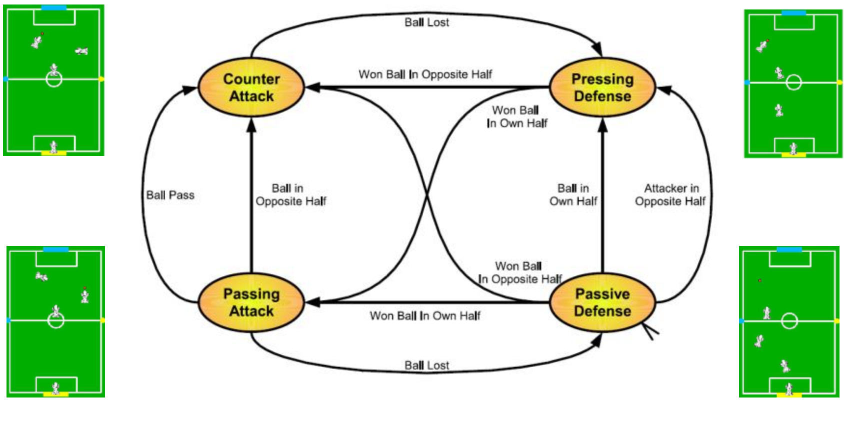
Petri net plan coordination for robocup teams
G. Kontes and M.G. Lagoudakis

Passing Maneuver



Teamwork Design Based on Petri Net Plan
P. F. Palamara, V. A. Ziparo, L. Iocchi, D. Nardi, and P. Lima

Team strategy



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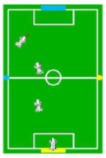
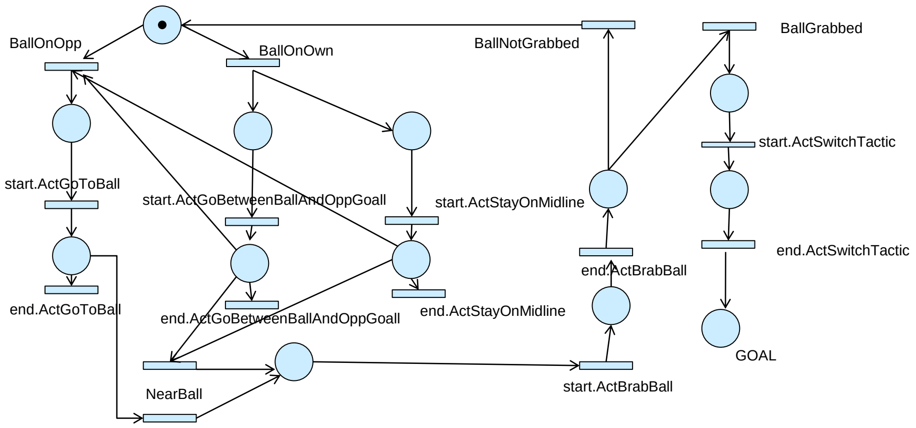
Attacker role
in the pressing defense tactic





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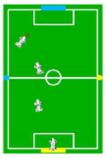
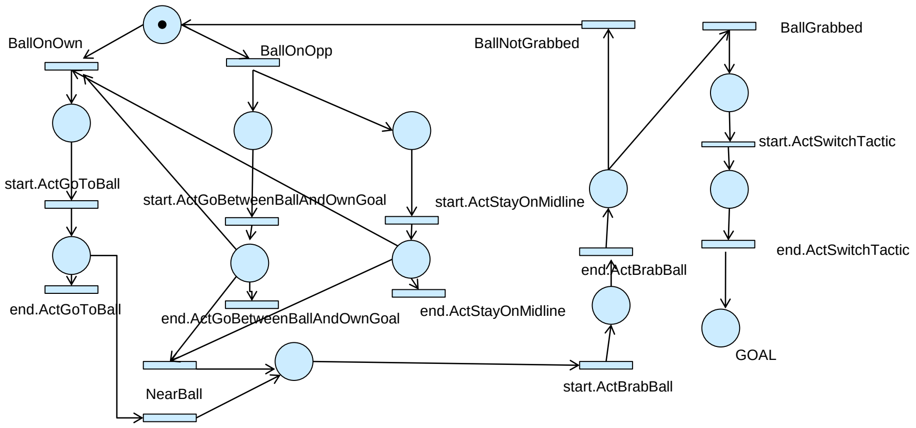
Midfielder role
in the pressing defense tactic





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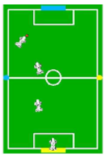
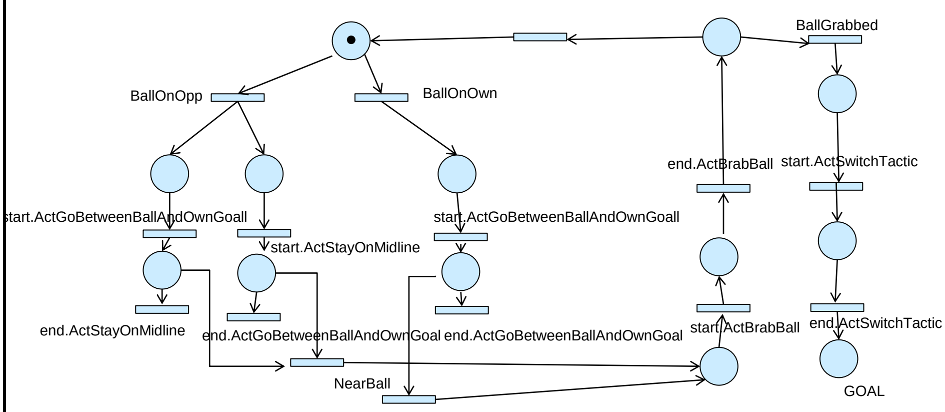
Defender role
in the pressing defense tactic





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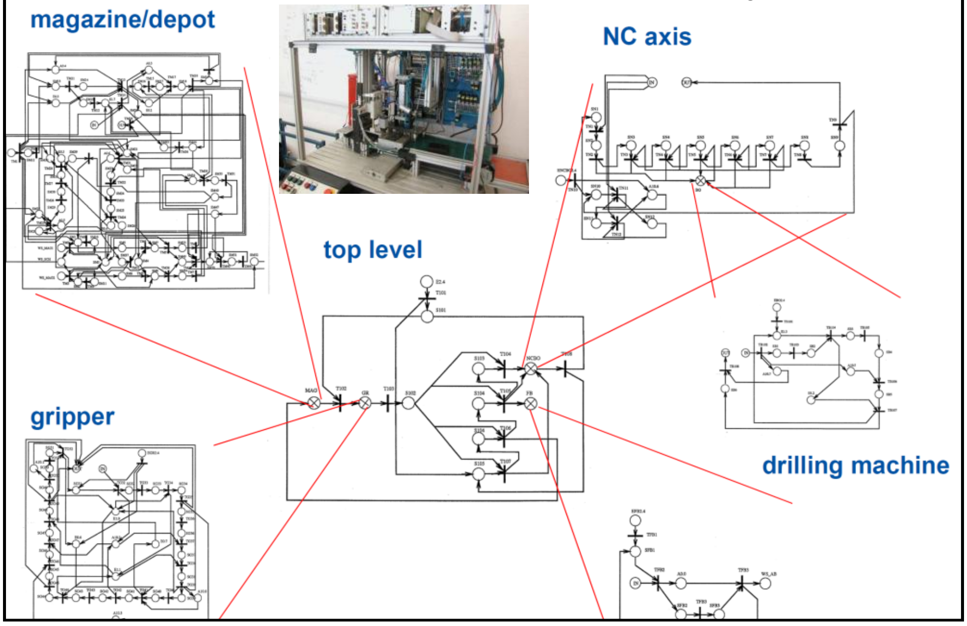
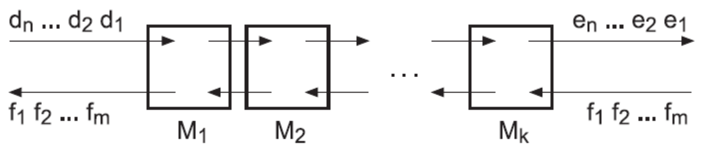
Production system

A modelbased realtime faultdiagnosis
system for technical processes
Ch. Steger, R. Weiss



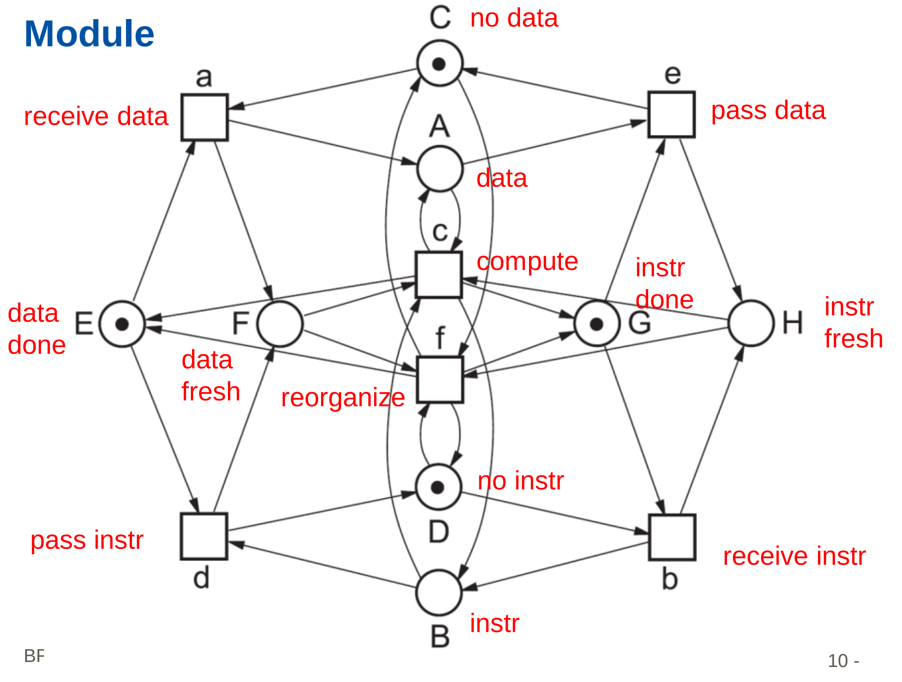
Sprout Counter Flow Pipeline-Processor



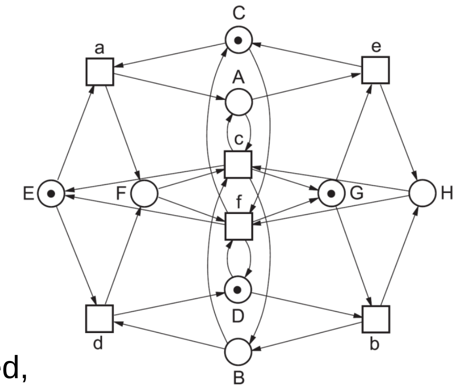
- Based on a stream of data packages $d_1 \ldots d_n$ and a stream of instructions $f_1 \ldots f_m$ compute $e_i =_{\text{def}} f_m(\ldots f_2(f_1(d_i))\ldots)$
- Data and instructions arrive asynchronously
- Execution times of instructions vary
- Data flows from left to right
- Instructions flow from right to left

Wolfgang Reisig: Petrinetze, Springer 2010

Module



Analysis



Place invariants:

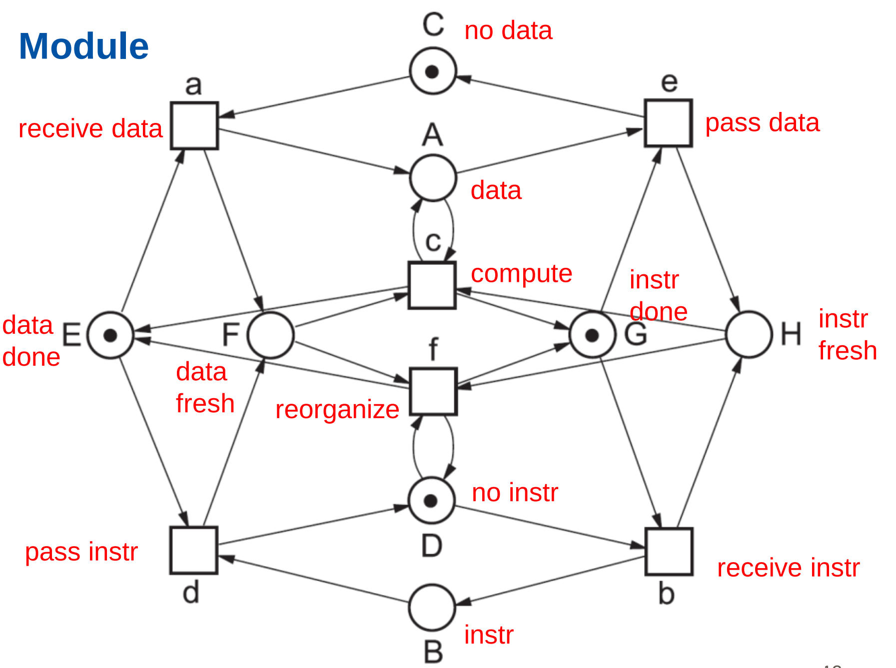
A + H + E + D = 2

B + D = 1

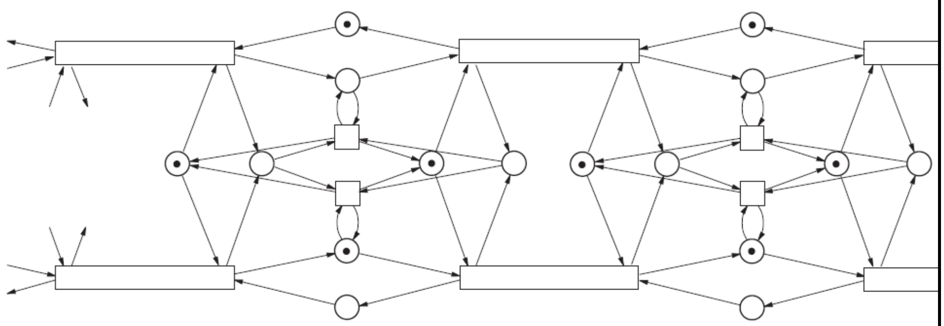
Hence, if A and H are marked,
B must also be marked.

The edges between B and c can be removed.
(Analogously for C and f.)

Module



Composition of modules

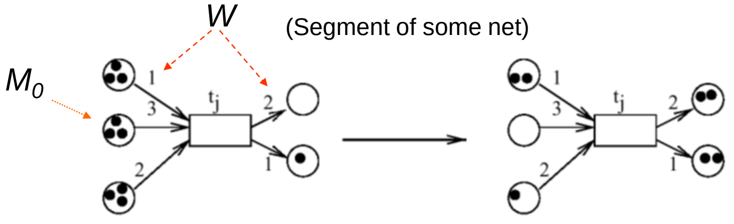


REVIEW: Place/transition nets

multiple tokens per place

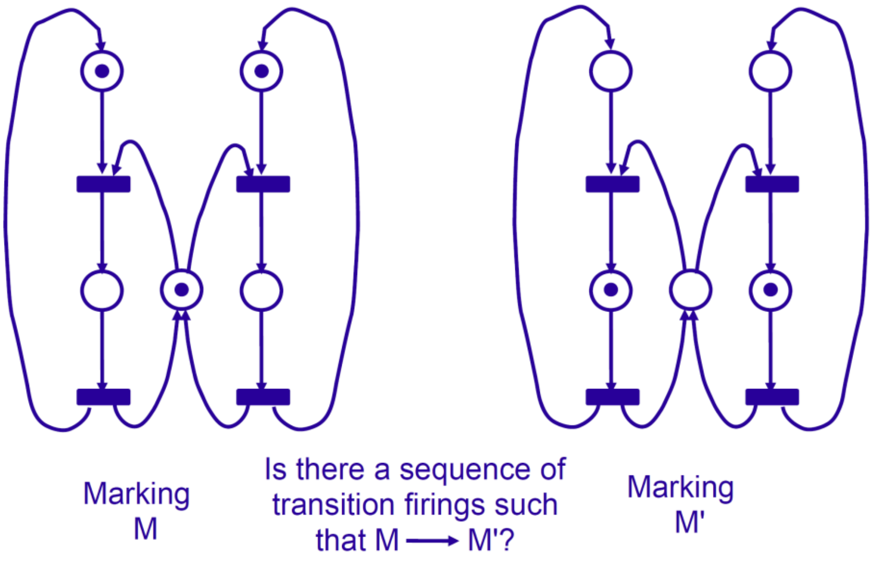
Def.: (P, T, F, K, W, M_0) is called a **place/transition net (P/T net)** iff

1. $N=(P,T,F)$ is a **net** with places P and transitions T
2. $K: P \rightarrow (\mathbf{N}_0 \cup \{\omega\}) \setminus\{0\}$ denotes the **capacity** of places (ω symbolizes infinite capacity)
3. $W: F \rightarrow (\mathbf{N}_0 \setminus\{0\})$ denotes the **weight of graph edges**
4. $M_0: P \rightarrow \mathbf{N}_0 \cup\{\omega\}$ represents the **initial marking** of places



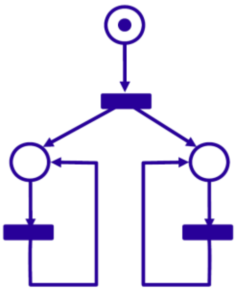
default:
K = ω
W = 1

REVIEW: Reachability

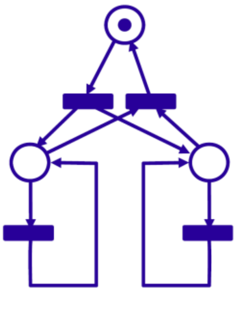


REVIEW: Liveness

- A transition is **live** if in every reachable marking there exists a firing sequence such that the transition becomes enabled
- A net is **live** if all its transitions are live

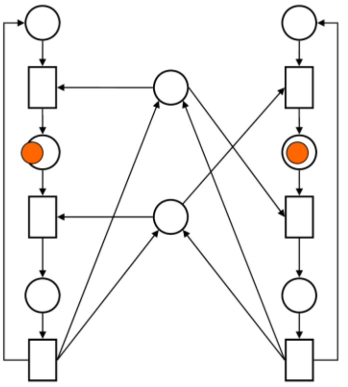


Live
?

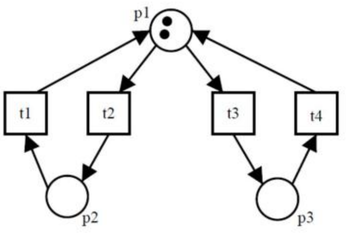


REVIEW: Deadlock

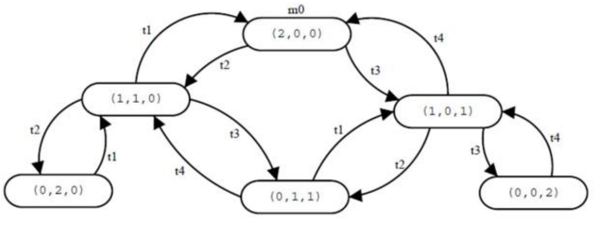
- A **dead marking** (**deadlock**) is a marking where no transition can fire
- A net is **deadlock-free** if no dead marking is reachable



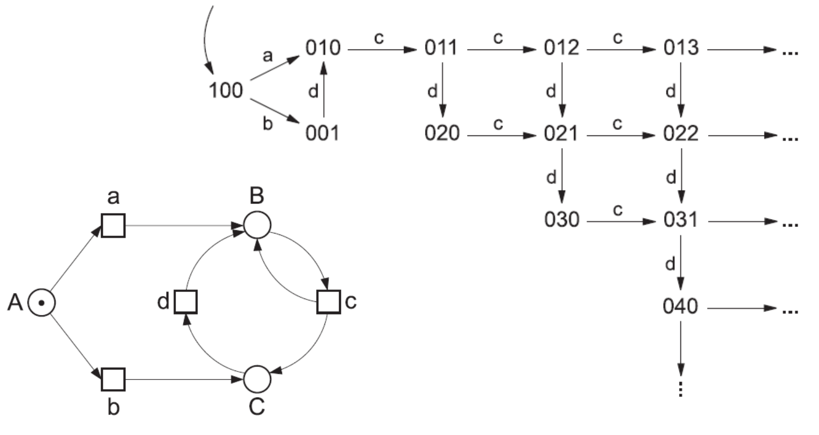
Reachability, Liveness, Deadlock are graph problems on reachability graph



Reachability graph:

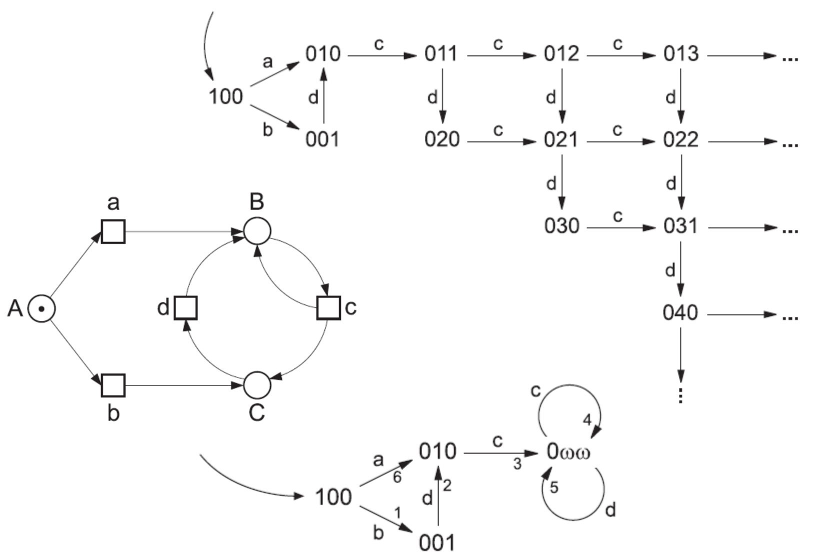


Reachability graph is in general infinite



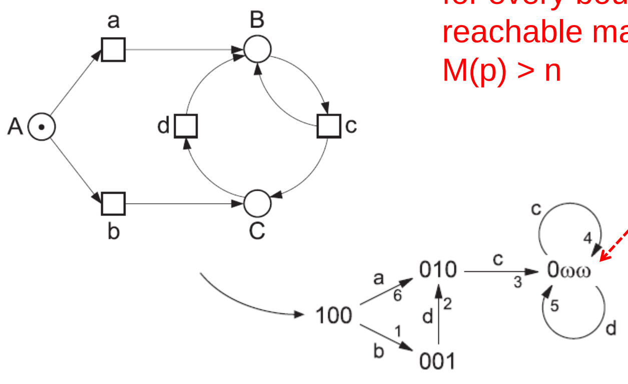
Example from Wolfgang Reisig: Petrinetze, Springer 2010

Coverability graph



Example from Wolfgang Reisig: Petrinetze, Springer 2010

Coverability graph



ω indicates that arbitrarily high values can be reached: for every bound n there is a reachable marking M with M(p) > n

Example from Wolfgang Reisig: Petrinetze, Springer 2010

Constructing the coverability graph

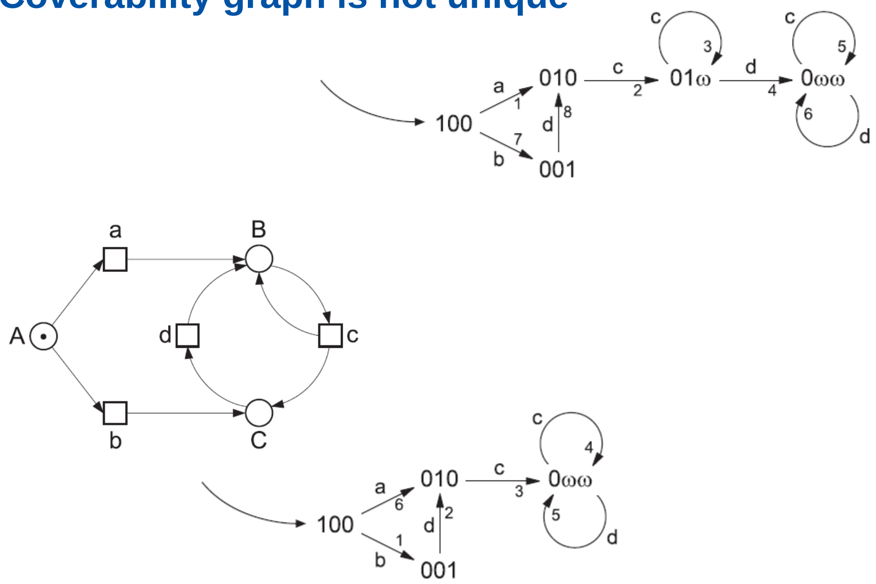
- The initial graph consists of the initial marking M_0
- Extend the graph as long as there exists a node *M* such that
  - a transition *t* can fire from *M* leading to some marking *M*'
  - but there is no outgoing edge from *M* labeled with *t*

Create a *t*-labeled edge from *M* to *M*'', where *M*'' is defined as follows:

M''(*p*) = ω if there exists a path from M_0 to *M* through some node *L* with $L \leq M'$ and $L(p) < M'(p)$

M''(*p*) = *M*'(*p*) otherwise

Coverability graph is not unique



Example from Wolfgang Reisig: Petrinetze, Springer 2010

Finiteness of the coverability graph

Theorem 2: Every P/T net has a finite coverability graph.

Lemma 1: Every infinite sequence of markings (M_i) contains a weakly monotonically growing infinite subsequence $(M`_i)$, i.e., for j<k, $M`_j \leq M`_k$.

(proof on blackboard)

Coverability theorem

A marking *M* **covers** a marking *M*' iff, for all places *p*,

$M(p) = M'(p)$ or $M(p) = \omega$.

A computation of a P/T net is a sequence

$$M_0 \xrightarrow{t_0} M_1 \xrightarrow{t_1} M_2 \xrightarrow{t_2} \ldots$$

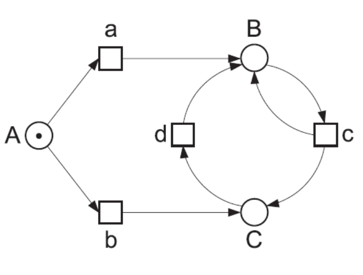
where M_0 is the initial marking and M_{i+1} is the result of firing transition t_i in marking M_i

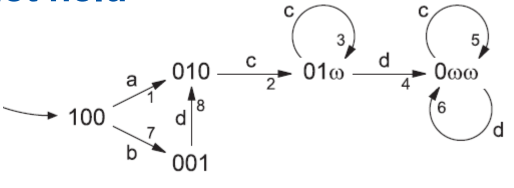
Theorem 3: For every computation

$M_0 \xrightarrow{t_0} M_1 \xrightarrow{t_1} M_2 \xrightarrow{t_2} \ldots$ of a P/T net there exists, in every coverability graph, a path

$M'_0 \xrightarrow{t_0} M'_1 \xrightarrow{t_1} M'_2 \xrightarrow{t_2} \ldots$ such that M'_i covers M_i for all *i*.

The converse does not hold



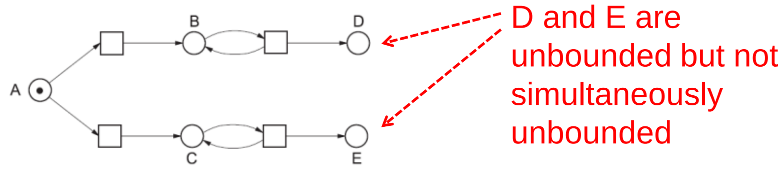


$$100 \xrightarrow{a} 010 \xrightarrow{c} 01\omega \xrightarrow{d} 0\omega\omega \xrightarrow{d} 0\omega\omega \cdots$$

Example from Wolfgang Reisig: Petrinetze, Springer 2010

Simultaneous unboundedness

A set *Q* of places is **simultaneously unbounded** iff, for every natural number *i*, there exists a reachable marking M^i where, for all $q \in Q$, $M^i(q) \geq i$.



Theorem 4: For every node M in a coverability graph of some P/T net, it holds that the places in ω_M, where $p \in \omega_M$ iff $M(p) = \omega$, are **simultaneously unbounded**.

(proof on blackboard)

Petri nets - summary

- Petri nets: focus on causal dependencies
- Condition/event nets
  - Single token per place
- Place/transition nets
  - Multiple tokens per place
- Predicate/transition nets
  - Tokens become individuals
- Advanced theory for analyzing properties
  (In general expensive. Reachability is EXPSPACE-hard.)