DUS

- diskrétne
- udalostné
- systémy

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S T U
F E I

SLOVENSKÁ TECHNICKÁ UNIVERZITA V BRATISLAVE
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Semantics of PN

Sekvenčná sémantika

- sekvencia spustení

Nesekvenčná sémantika

- kroková sekvencia
- označené čiastočné usporiadanie (multimnožiny prechodov)
- procesy
- výrazy

Semantics of PN

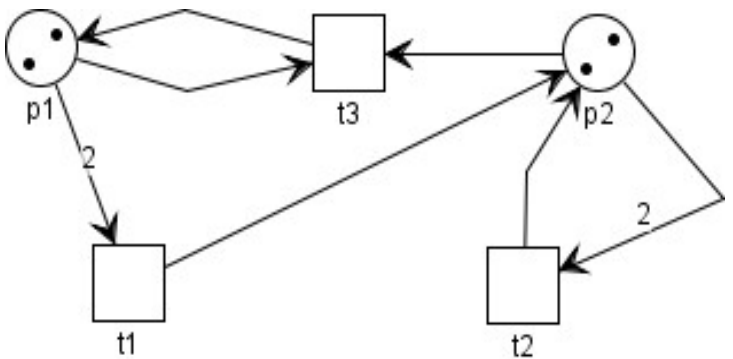
Scénar je daný sekvenciou udalostí.

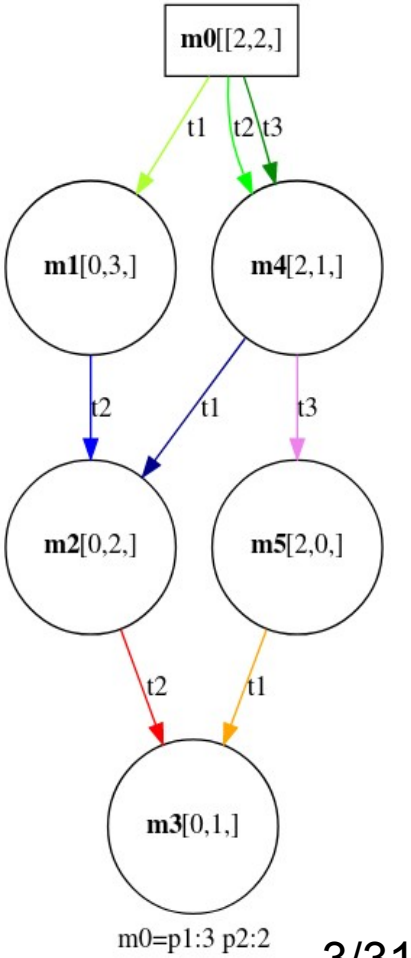
Udalosť je daná spustením prechodu t v PS.

prepisovacie pravidlá scénaru z grafu dosiahnuteľnosti:

- **kauzalita ‘;‘**
- **paralelizmus ‘+‘**

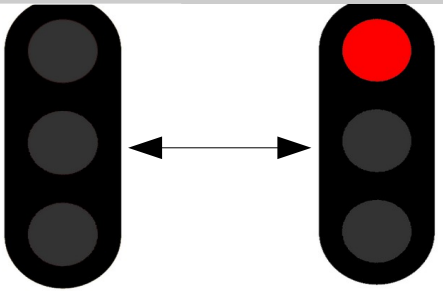
{t1;t2;t2},
{t2;t1;t2},
{t2;t3;t1},
{t3;t3;t1},
{t3;t1;t2}

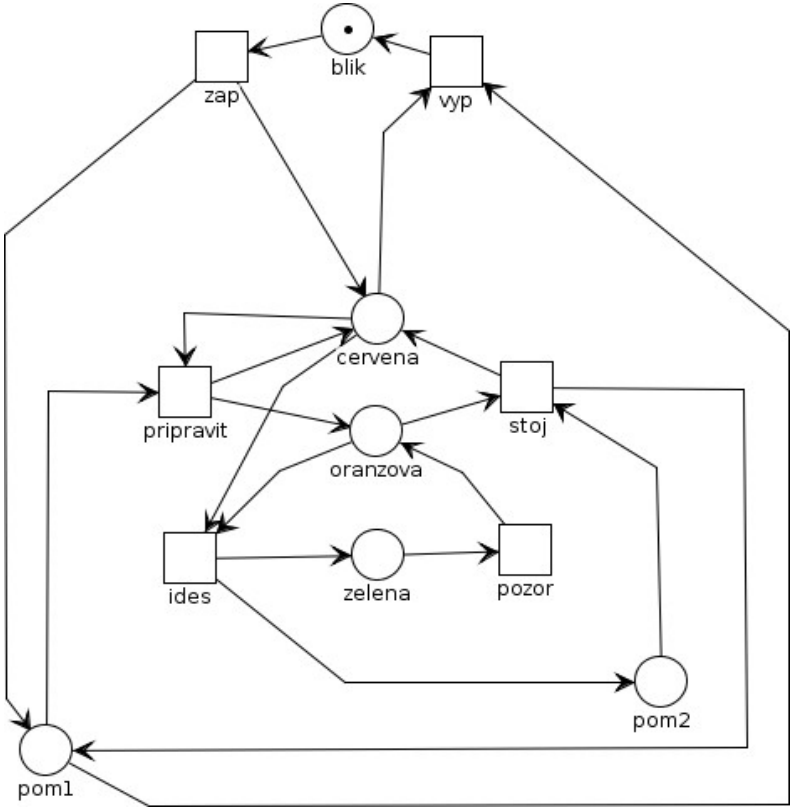




PN reachability

stav semaforu	povolené udalosti	značkovanie
vypnutý	zap	1,0,0,0,0,0
státie (zapnutý)	vyp, prip	0,1,0,1,0,0
pripravený-voľno	ides	0,1,1,0,0,0
voľný	pozor	0,0,0,0,1,1
pripravený-stoj	stoj	0,0,1,0,1,0





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PN

Ako vytvoriť softvér – rýchlo, lacno a v dobrej kvalite

Špecifikácia, Model driven development,Rapid system prototyping, …

Ako vytvoriť model – rýchlo, lacno a v dobrej kvalite

(semi) automaticky

PN

Záznamy ...

Model….

Process Mining
Syntéza
Identifikácia

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PN

Scénare: {F;C;A;B;D;E;F;C}, {F;E;F;E;F}, {F;C;A;B;D;C;A;B;D;C}

Stav semaforu	udalosti	značkovanie
?	zapnutie	??
?	pripravený	??
?	ides	??
?	pozor	??
?	stoj	??
?	vypnutie	??
?	zapnutie	??
?	pripravený	??

Stav semaforu	udalosti	značkovanie
?	zapnutie	??
?	vypnutie	??
?	zapnutie	??
?	vypnutie	??
?	zapnutie	??

Stav semaforu	udalosti	značkovanie
?	zapnutie	??
?	pripravený	??
?	ides	??
?	pozor	??
?	stoj	??
?	pripravený	??
?	ides	??
?	pozor	??
?	stoj	??
?	pripravený	??

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PN Synthesis from sequence scenarios

- Metóda konečnej bázy prípustných miest
- **Metóda nesprávnych pokračovaní (WC)**
- Metóda toku značení

WC: Wrong continuations

Sekvencie v scénari

- Gener. nerovníc z pozorovaných scénarov
- Gener. nerovníc zabraňujúce nepozorovanych scénarov
- Riešenie …
- Optimalizácia ?

WC: Wrong continuations

Pozorované scénare: {**a;b;d**}, {**a;c;d**}

identifikácia udalosti ...

Záznamy<id> <udalosť>:

0 a
0 b
1 a
1 c
0 d
1 d

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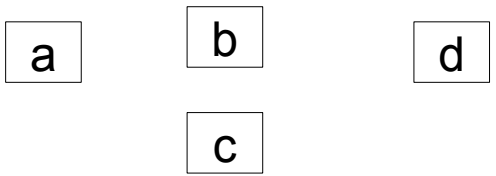
WC: Wrong continuations

Pozorované scénare: {**a;b;d**}, {**a;c;d**}
Sekvencia **a;b;d**:
Sekvencia **a;c;d**:



Záznamy<id> <udalosť>:

0 a
0 b
0 d

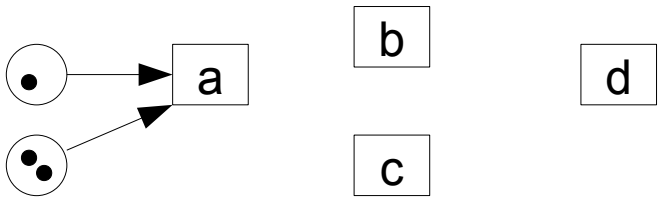
1 a
1 c
1 d

WC: Wrong continuations

Pozorované scénare: {**a;b;d**}, {**a;c;d**}

Sekvencia **a;b;d**: $m \geq a_z$;

Sekvencia **a;c;d**: $m \geq a_z$;



$\mathbf{m^T_x = m^T + C.X^T}$

$\mathbf{m^T \geq I.X^T}$

T = {a,b,c,d};

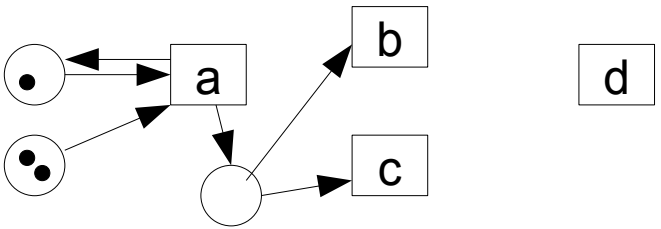
$X_a=(1,0,0,0)$

$\mathbf{I.X_a^T == a_z}$

$\mathbf{m^T \geq a_z}$

WC: Wrong continuations

Pozorované scénare: {**a;b;d**}, {**a;c;d**}
Sekvencia **a;b;d**: $m \geq a_z$; $m \geq a_z - a_d + b_z$;
Sekvencia **a;c;d**: $m \geq a_z$; $m \geq a_z - a_d + c_z$;



$m^T_x = m^T + C.X^T$
$\mathbf{m^T_x = m^T + O.X^T - I.X^T}$
$m^T \geq I.X^T$

$T = \{a,b,c,d\}$;
$X_a=(1,0,0,0); X_b=(0,1,0,0); X_c=(0,0,1,0)$
$\mathbf{I.X_a^T == a_z \;\; ; I.X_b^T == b_z \;\; ; I.X_c^T == c_z}$
$\mathbf{O.X_a^T == a_d}$

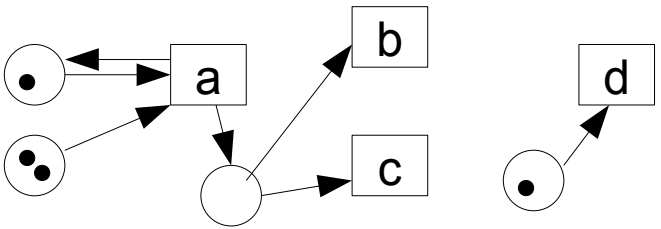
$\mathbf{m^T_a \geq I.X^T_b}$
$m^T_a = m^T + O.X^T - I.X^T = m^T - a_z + a_d$
$m^T - a_z + a_d \geq b_z$
$\mathbf{m^T \geq a_z - a_d + b_z}$

WC: Wrong continuations

Pozorované scénare: {**a;b;d**}, {**a;c;d**}

Sekvencia **a;b;d**: $m \geq a_z$; $m \geq a_z - a_d + b_z$; $m \geq a_z - a_d + b_z - b_d + d_z$;

Sekvencia **a;c;d**: $m \geq a_z$; $m \geq a_z - a_d + c_z$; $m \geq a_z - a_d + c_z - c_d + d_z$;



$X_a; X_b; X_c; X_d$

$a_z \;\; b_z \;\; c_z \;\; d_z$

$a_d \;\; b_d \;\; c_d \;\; d_d$

$\mathbf{m^T_{ab} \geq I.X^T_d}$

$m^T_{ab} = m^T_a + O.X^T_b - I.X^T_b = m^T_a - b_z + b_d =$

$= m^T - a_z + a_d + b_z - b_d$

$\mathbf{m^T \geq a_z - a_d + b_z - b_z + d_d}$

WC: Wrong continuations

Pozorované scénare: {**a;b;d**}, {**a;c;d**}

Sekvencia **a;b;d**: $m \geq a_z$; $m \geq a_z - a_d + b_z$; $m \geq a_z - a_d + b_z - b_d + d_z$;

Sekvencia **a;c;d**: $m \geq a_z$; $m \geq a_z - a_d + c_z$; $m \geq a_z - a_d + c_z - c_d + d_z$;

Sekvencie {**b**},{**c**},{**d**}: $m < b_z$; $m < c_z$; $m < d_z$; ďalej...

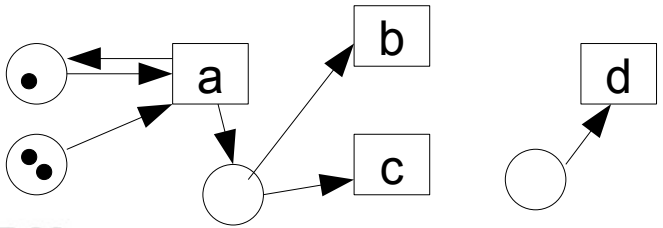
$X_a; X_b; X_c; X_d$

$a_z \;\; b_z \;\; c_z \;\; d_z$

$a_d \;\; b_d \;\; c_d \;\; d_d$

$\mathbf{m^T < I.X^T_b}$; $\mathbf{m^T < I.X^T_c}$; $\mathbf{m^T < I.X^T_d}$

$\mathbf{m^T < b_z}$ …



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WC: Wrong continuations

Pozorované scénare: {**a;b;d**}, {**a;c;d**}

Sekvencia **a;b;d**: $m \geq a_z$; $m \geq a_z - a_d + b_z$; $m \geq a_z - a_d + b_z - b_d + d_z$;

Sekvencia **a;c;d**: $m \geq a_z$; $m \geq a_z - a_d + c_z$; $m \geq a_z - a_d + c_z - c_d + d_z$;

Sekvencie {**b**},{**c**},{**d**}: $m < b_z$; $m < c_z$; $m < d_z$; ďalej

Sekvencie {**(a);d**},{**(a);a**}: $m < a_z - a_d + d_z$; $m < 2a_z - a_d$; …

X_m=(a,b,c,d); X_s=(a,b,c,d);
minulosť spustenie{X_a;X_b;X_c;X_d}

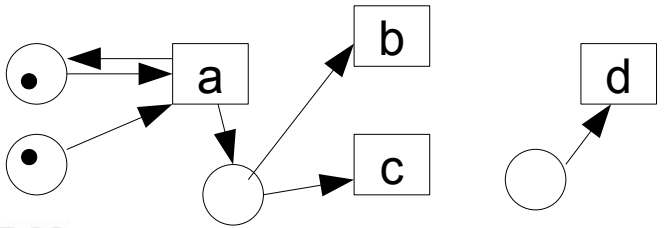
$$\mathbf{m^T_m \geq I.X^T_s}$$

$$m^T_m = m^T + O.X^T_m - I.X^T_m = m^T \ldots +/- \ldots$$

$$\mathbf{m^T_a < I.X^T_d}$$

$$\mathbf{m^T + O.X^T_a - I.X^T_a < I.X^T_d}$$

$$\mathbf{m^T < a_z - a_d + d_z}$$



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WC: Wrong continuations

Pozorované scénare: {**a;b;d**}, {**a;c;d**}

Sekvencia **a;b;d**: $m \geq a_z$; $m \geq a_z - a_d + b_z$; $m \geq a_z - a_d + b_z - b_d + d_z$;

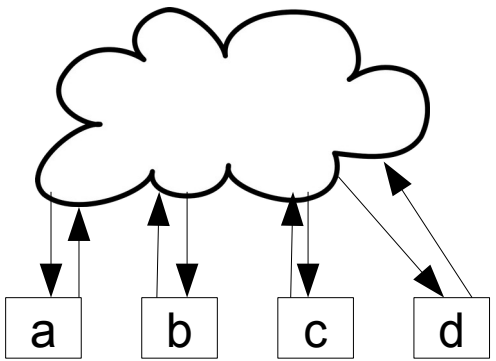
Sekvencia **a;c;d**: $m \geq a_z$; $m \geq a_z - a_d + c_z$; $m \geq a_z - a_d + c_z - c_d + d_z$;

Sekvencie {**b**},{**c**},{**d**}: $m < b_z$; $m < c_z$; $m < d_z$; ďalej

Sekvencie {**(a);d**},{**(a);a**}: $m < a_z - a_d + d_z$; $m < 2a_z - a_d$;

Sekvencie {**(ab);a**},{**(ab);b**},{**(ab);c**}, {**(ac);a**},{**(ac);b**},{**(ac);c**}

Sekvencie {**(abd);a**},{**(abd);b**},{**(abd);c**},{**(abd);d**},
{**(acd);a**},{**(acd);b**},{**(acd);c**},{**(acd);d**}



X_m=(a,b,c,d); X_s=(a,b,c,d);
minulost spustenie{X_a;X_b;X_c;X_d}

$\mathbf{m^T_m \geq I.X^T_s}$

$m^T_m = m^T + O.X^T_m - I.X^T_m = m^T$ ...+/- ...

$m^T_a < I.X^T_d$

$m^T + O.X^T_a - I.X^T_a < I.X^T_d$

$m^T < a_z - a_d + d_z$

$\mathbf{m^T_{acd} < I.X^T_a}$

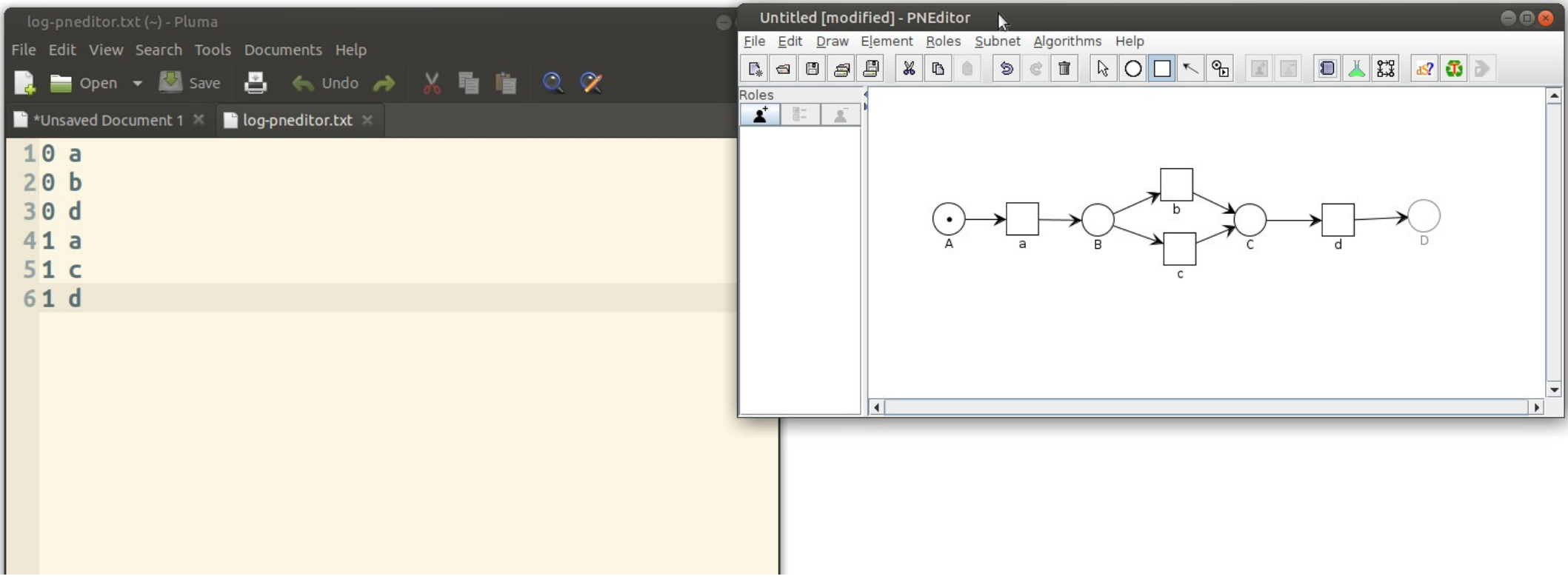
$\mathbf{X_m = (1,0,1,1);\quad X_s = (1,0,0,0);}$

$m^T + O.X^T_{acd} - I.X^T_{acd} < I.X^T_a$

$\mathbf{m^T < a_z - a_d + c_z - c_d + d_z - d_d + a_z}$

...

WC: Wrong continuations



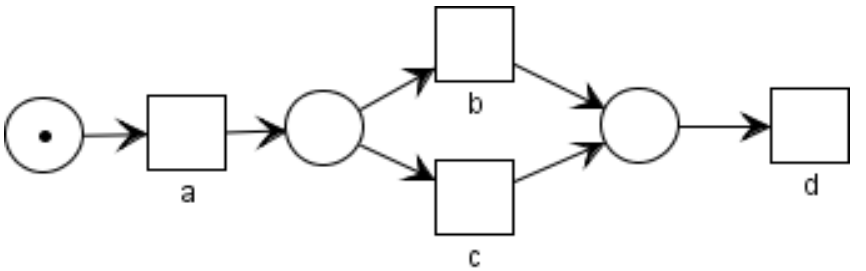
WC: Wrong continuations

5(6) nerovníc pre RC – 2 p.s.

4 prechody / udalosti, (vytv. komb. horného ohraničenia)

3+2+6+8=19 rovníc WC nesprávnych pokračovaní

Ekvivalencia v PN (Simple, Bisimulation, ST-bisimulation, History preserving bisimulation)



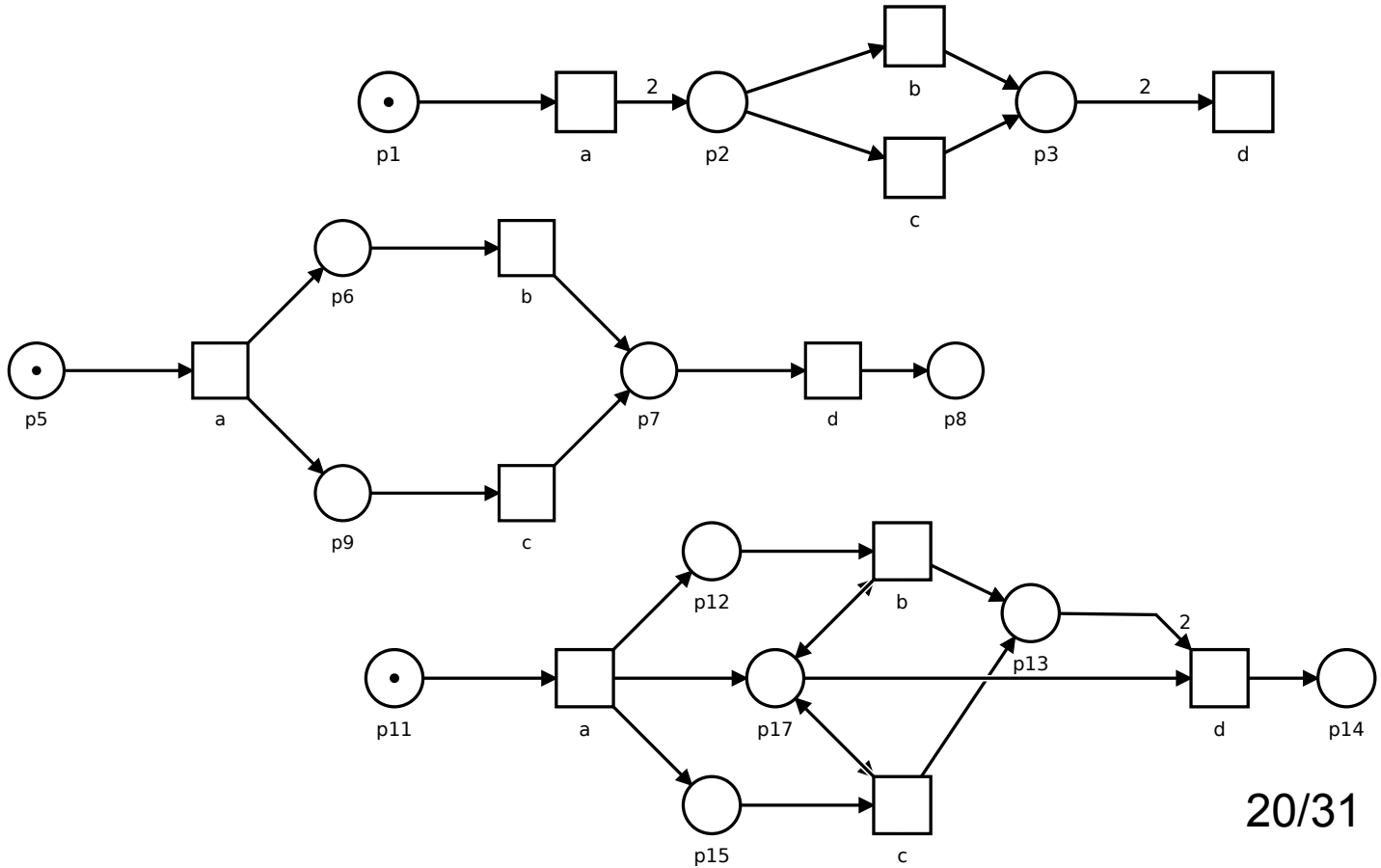
WC: Wrong continuations

Ekvivalencia v PN

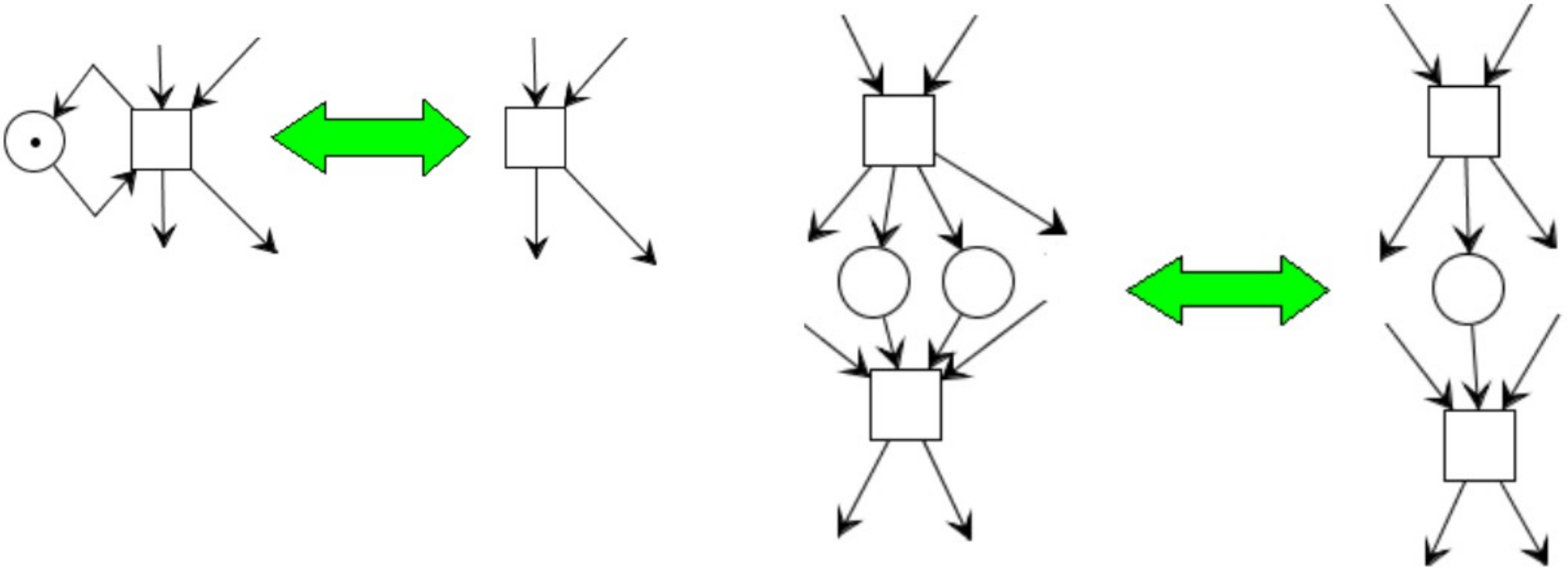
- Zober tácku (a)
- Zober vidličku (b)
- Zober tanier (c)
- Jedz (d)

{a;b;c;d}

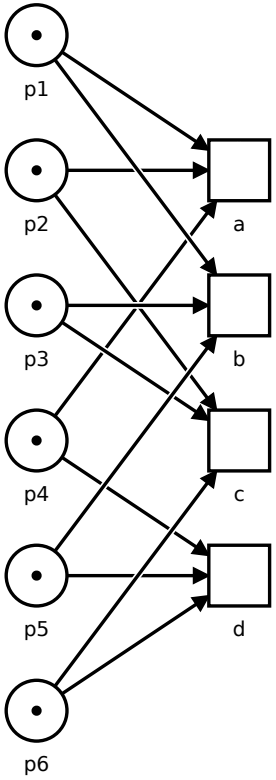
{a;c;b;d}

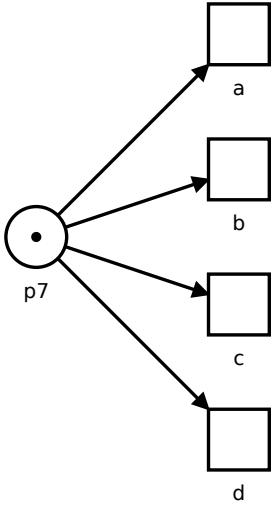


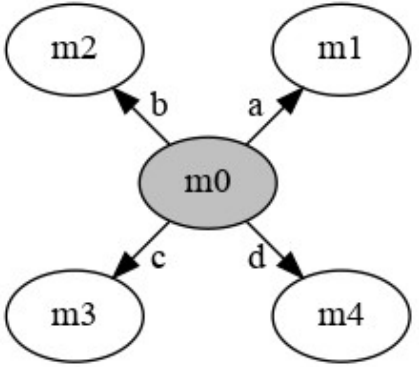
Equivalence - Reduction

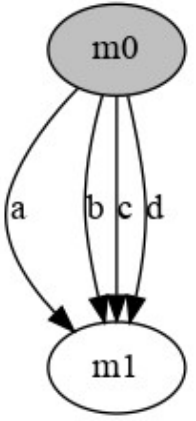


Equivalences in PN









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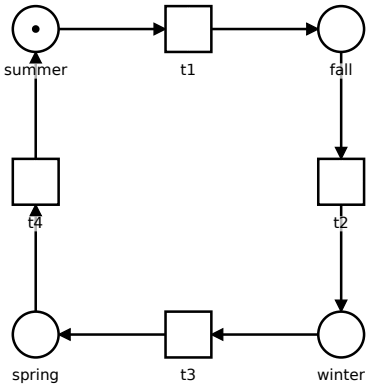
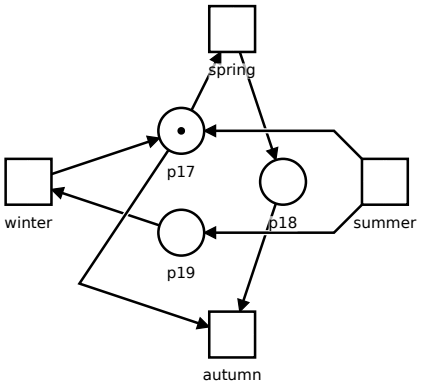
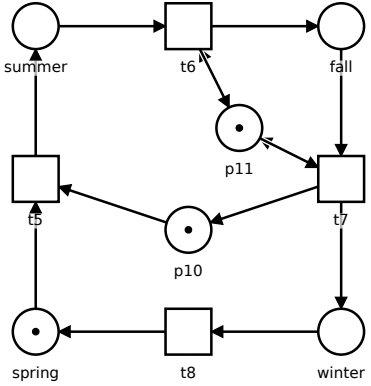
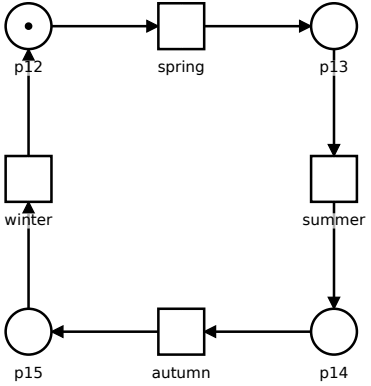
Equivalences in PN









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Equivalences in PN

Ekvivalencia → izomorfizmus → bijekcia (reflex., symetr.,tranzit.)

Sú grafy (f,g) izomorfné (P?, NP?, NP-compl.?)

László Babai (Group, graphs, algorithms: the graph isomorphism problem, 2018), kvázi-polynomial time

Marking, Trace and Language, Bisimulation

(Simple, Bisimulation, ST-bisimulation, History preserving bisimulation)

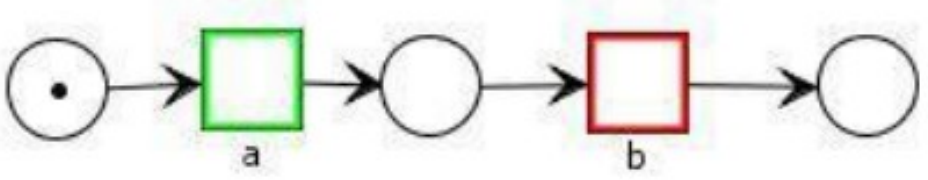
Marking Equivalence

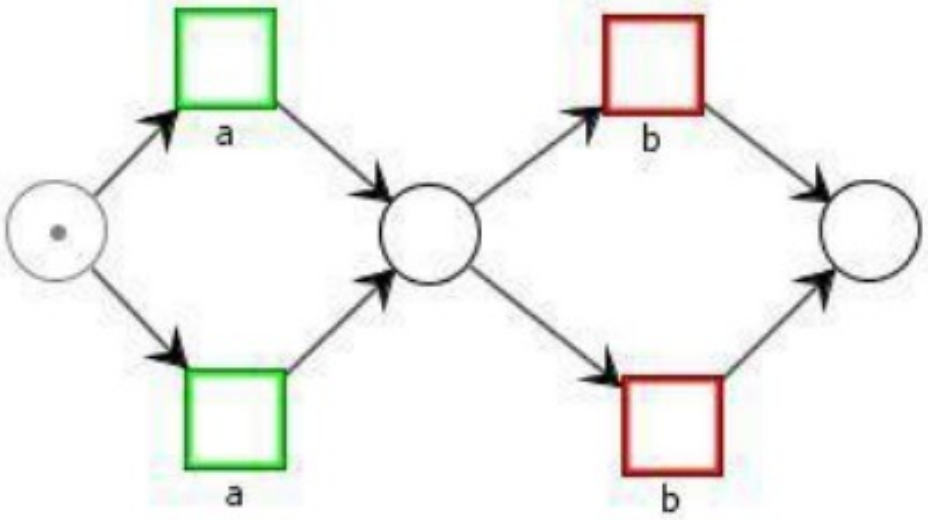
Dve PS majúce rovnakú množinu miest sú ekvivalentné, ak majú rovnakú množinu dosiahnuteľných značení.

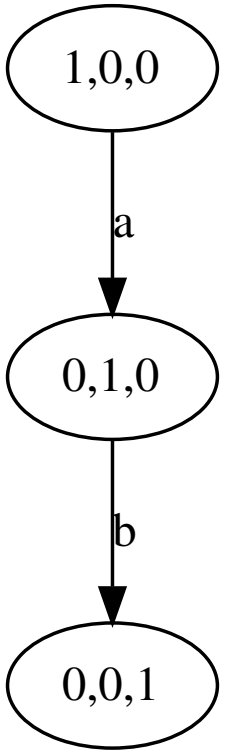
Problém ekvivalencie značenia je rozhodnuteľný pre ohraničené PS.

Pre neohraničené PS nevieme rozhodnúť či je sieť ekvivalentná.

Graf dosiahnutelnosti -> izomorfizmus







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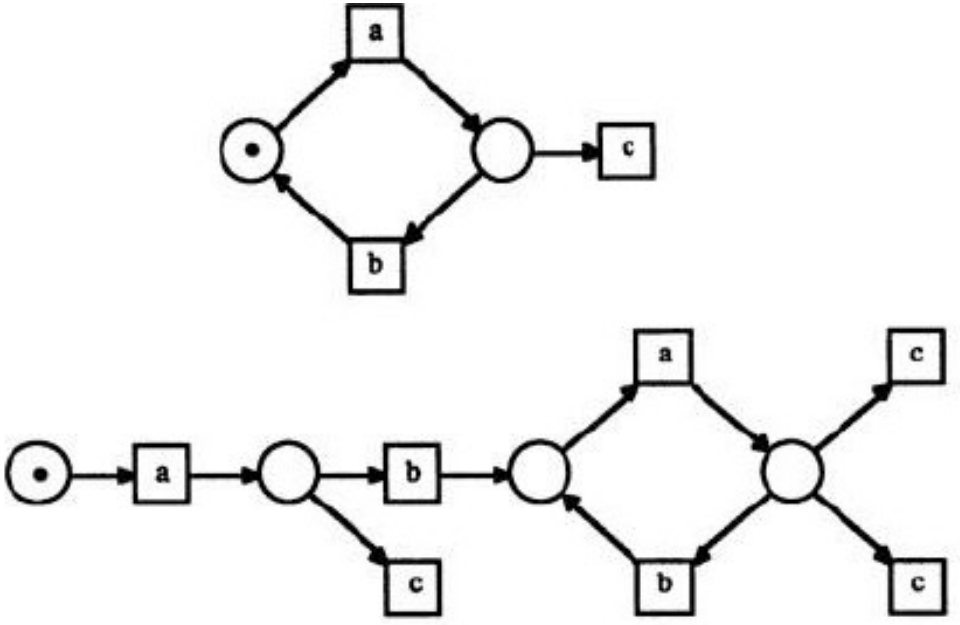
Trace and language equivalences

-- Dve **označené** PS sú trace(stopovo) ekvivalentné (jazykovo ekvivalentné) ak majú rovnakú množinu stôp (jazyk).

-- Nerozhodnuteľné pre viac ako 1 neohraničené miesto.

Bisimulation equivalence

-- Dve označené Petriho siete sú bisimulačne ekvivalentné, ak ich grafy dosiahnuteľnosti sú silno bisimulačne ekvivalentné.



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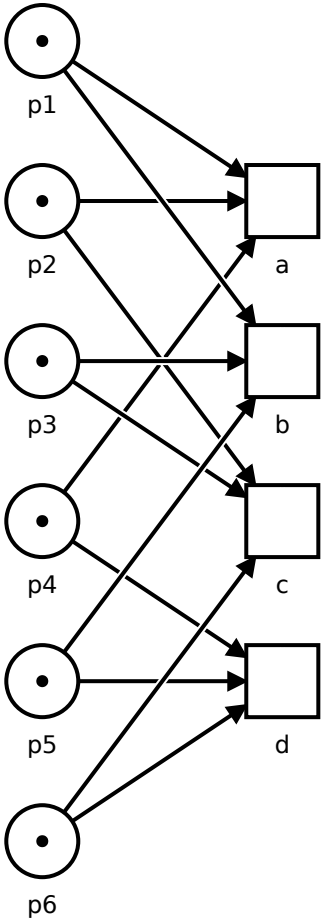
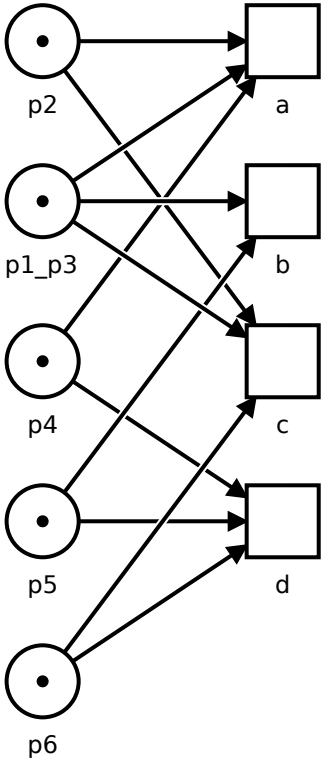
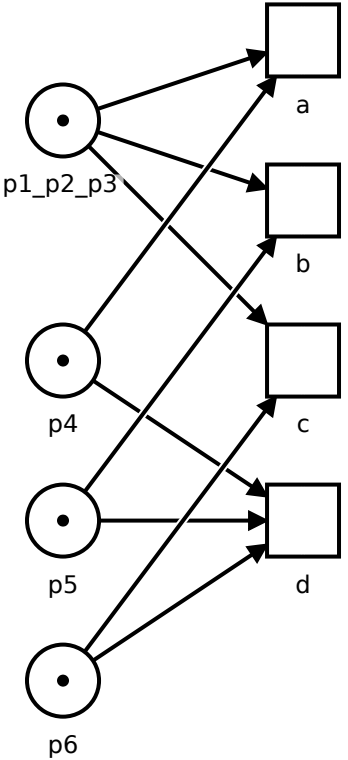
Equivalences in PN







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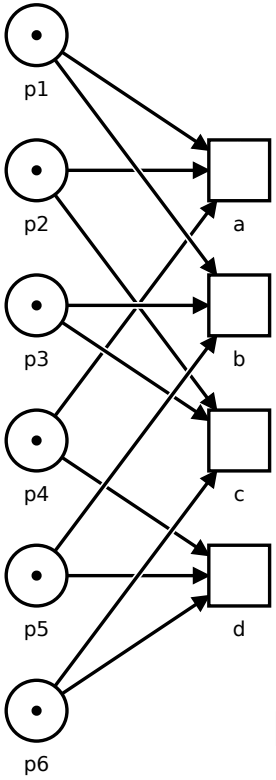
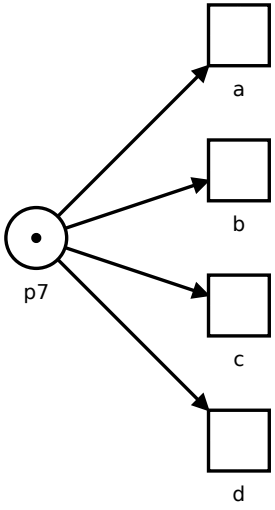
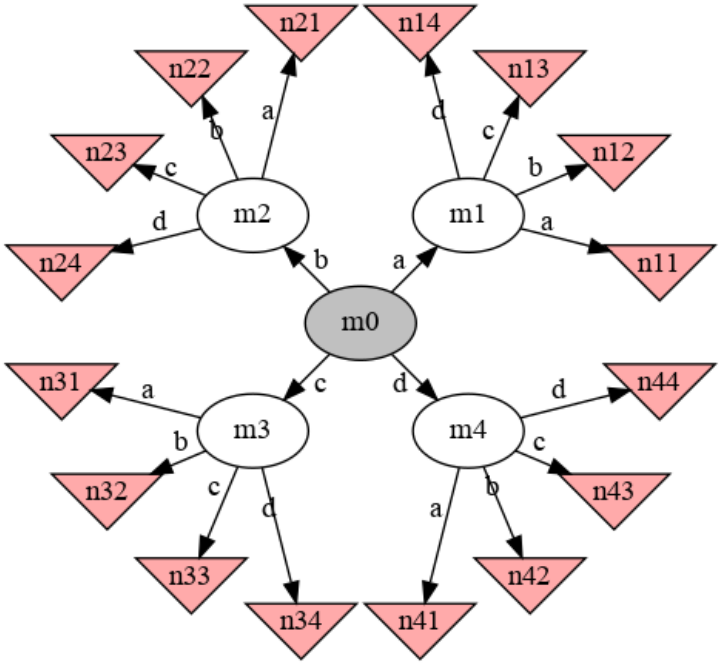
Synthesis from sequences








```
digraph { rankdir=TB; ranks
node [shape="ellipse" fixed
  m0 [ style="filled" fillcolor

  m0->m1 [label=a]
  m0->m2 [label=b]
  m0->m3 [label=c]
  m0->m4 [label=d]

  node [shape=invtriangle
  m1 -> n11 [label=a]
  m1 -> n12 [label=b]
  m1 -> n13 [label=c]
  m1 -> n14 [label=d]

  m2 -> n21 [label=a]
  m2 -> n22 [label=b]
  m2 -> n23 [label=c]
  m2 -> n24 [label=d]

  m3 -> n31 [label=a]
  m3 -> n32 [label=b]
  m3 -> n33 [label=c]
  m3 -> n34 [label=d]

  m4 -> n41 [label=a]
  m4 -> n42 [label=b]
  m4 -> n43 [label=c]
  m4 -> n44 [label=d]
}
```

Problémy:
- opakovanie stavov?
- cykly, či reverzibilnosť?
- konzistentnosť ?
- úplnosť ?

STU FEI

Synthesis from sequences

- Pozorovanie existujúcich scénarov (úplných i čiastočných).
- Analýza udalostí, identifikácia.
- Generovanie nerovníc z pozorovaných scénarov.
- Generovanie nerovníc zabraňujúce scénare.
- Riešenie sústav nerovníc, tvorba miest a značiek a hrán
- Riešenie vhodnej redukcie modelu systému, ekvivalencie PS.