Model-checking Real-time Systems with Roméo

École d'été Temps Réel 2017

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Roméo

- Roméo is a tool for the verification of Time Petri Nets;
- Developed since 2001 by Olivier H. Roux and Didier Lime;
- Written in C++ (engine, ∼24K loc) and Tcl/Tk (GUI, ∼18K loc);
- Distributed under the terms of the CeCILL **open source** license;
- Available at:

  `http://romeo.rts-software.org`

What can we model with Roméo?

- Complex interactions → **Petri nets**;
- Complex discrete behaviors → **discrete variables**;
- Timing uncertainty → **time intervals**;
- Preemptive scheduling → **stopwatches**;
- Design uncertainty → **parameters**;
- Soft real-time constraints, or energy constraints → **cost optimisation**.

Roméo: Some Success Stories

- Analysis of resilience properties in oscillatory **biological** systems [AMI16];
- Environment requirements for an aerial **video tracking** system (with Thales Research) [PRH+16];
- **Operational scenarios** modelling in the DGA OMOTESC project (with Sodius Nantes, Charlotte Seidner's Ph. D.) [Sei09].

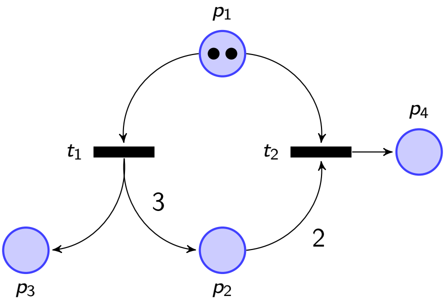
Outline

Introduction

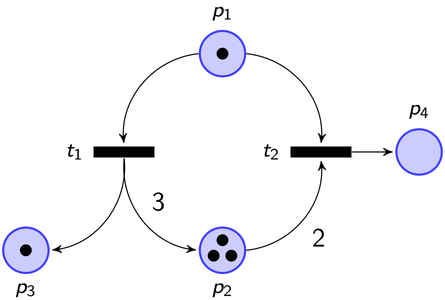
Time Petri Nets

Conclusion

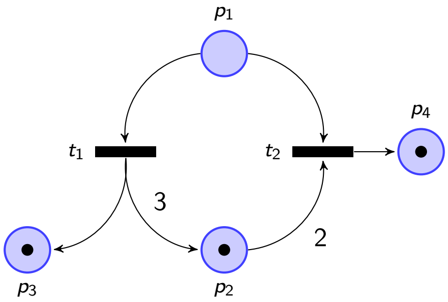
Petri Nets



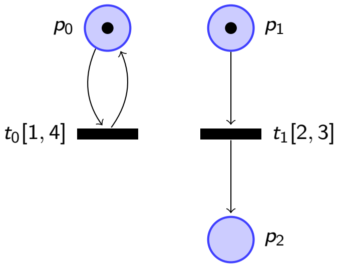
Petri Nets



Petri Nets



Time Petri Nets



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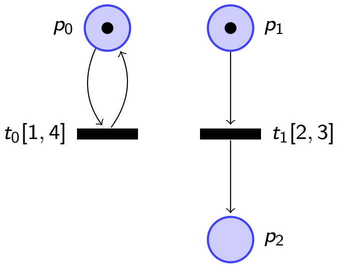
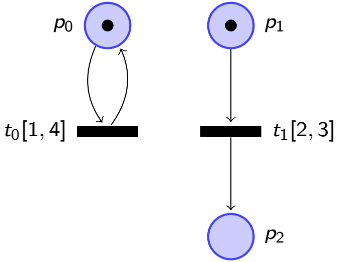


$t_0 \in [1,4]$
$t_1 \in [2,3]$

Time Petri Nets



$$\begin{matrix} t_0 \in [1,4] \\ t_1 \in [2,3] \end{matrix} \xrightarrow{1.1} \begin{matrix} [0, 2.9] \\ [0.9,\ 1.9] \end{matrix}$$

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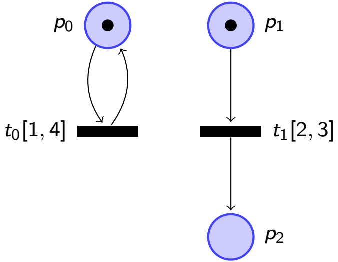

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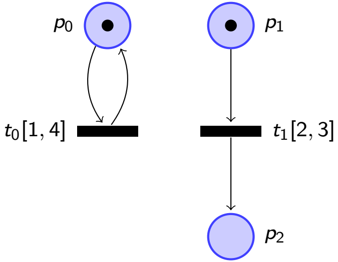

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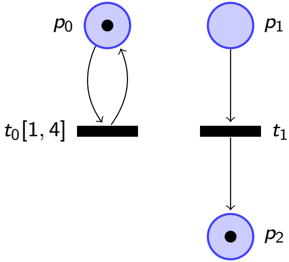
Time Petri Nets



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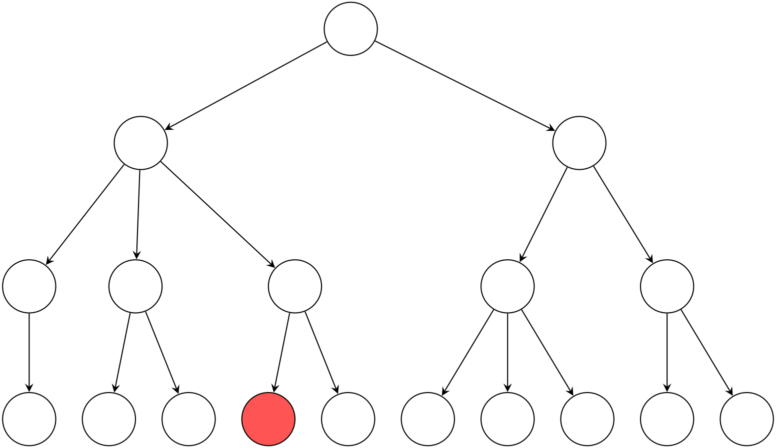
Basic Properties

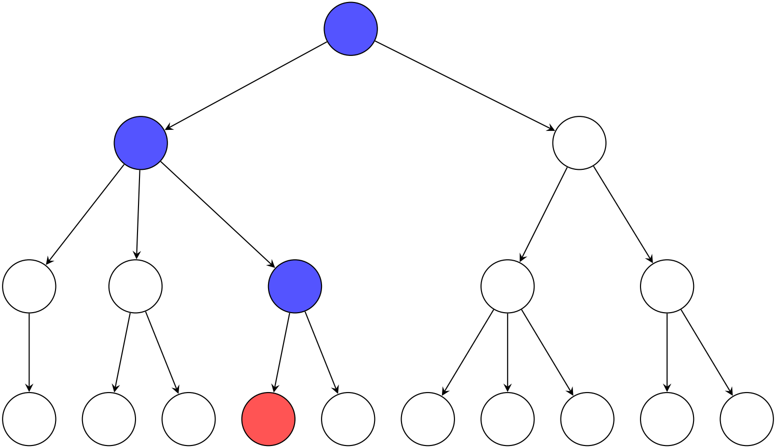
- The **non-nested** fragment of TCTL + (bounded) **response**;
- **Marking** properties are either:
  - linear constraints on the marking: $p_1 + 2 * p_2 > 4$
  - a boundedness property: `bounded(1)`
  - a deadlock property: `deadlock`
- **Temporal** properties (ϕ, ψ are marking properties):
  - $\mathtt{E}\,\phi\,\mathtt{U}\,[3,4]\,\psi$: there is a path on which ψ eventually holds in 3 to 4 t.u. and ϕ holds in the meantime;
  - $\mathtt{A}\,\phi\,\mathtt{U}\,[3,4]\,\psi$: on all paths ψ eventually holds in 3 to 4 t.u. and ϕ holds in the meantime;
  - $\phi -- > [0,5]\psi$: whenever ϕ holds, on all subsequent paths ψ holds within 5 t.u.
- Classic **shorthands**:
  - $\mathtt{EF}\,[3,4]\,\psi = \mathtt{E}\,\mathtt{true}\,\mathtt{U}\,[3,4]\,\psi$: reachability;
  - $\mathtt{AF}\,[3,4]\,\psi = \mathtt{A}\,\mathtt{true}\,\mathtt{U}\,[3,4]\,\psi$: inevitability;
  - $\mathtt{EG}\,\psi = \neg\mathtt{AF}\,(\neg\psi)$: preservability;
  - $\mathtt{AG}\,\psi = \neg\mathtt{EF}\,(\neg\psi)$: safety.

Basic properties



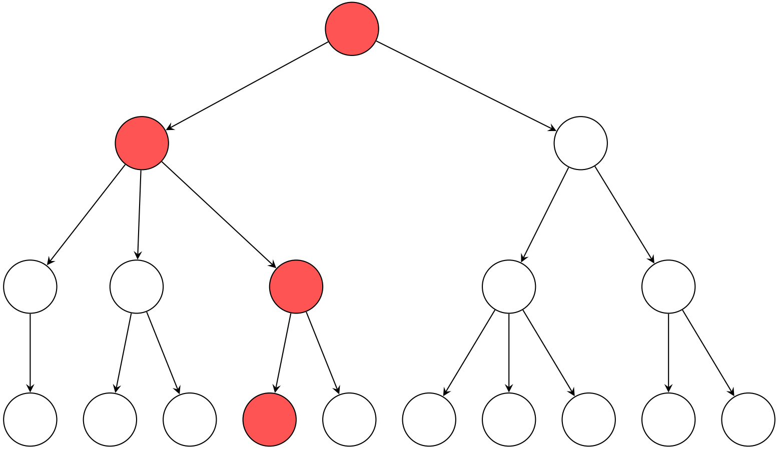
EFφ

Basic properties



$\mathbf{E}\varphi\mathbf{U}\psi$

Basic properties



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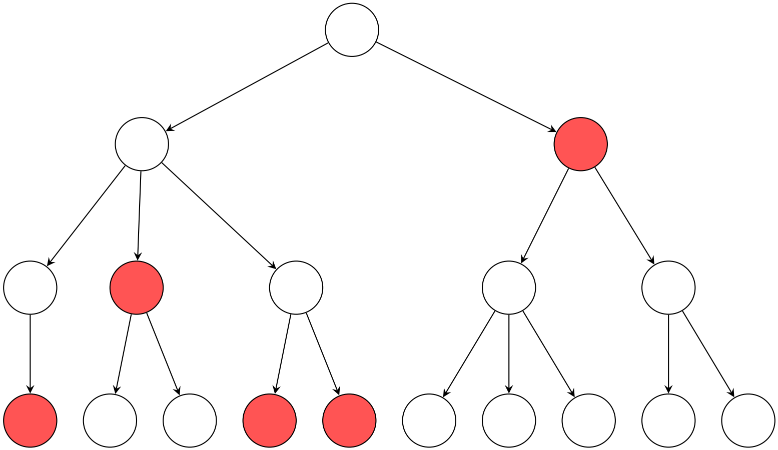

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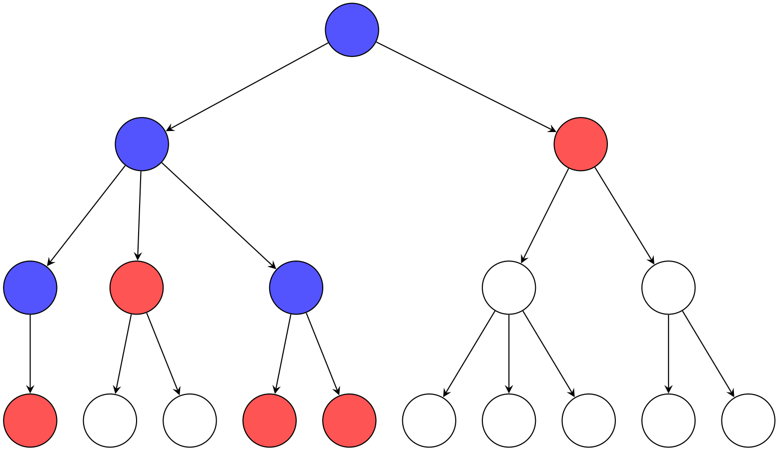

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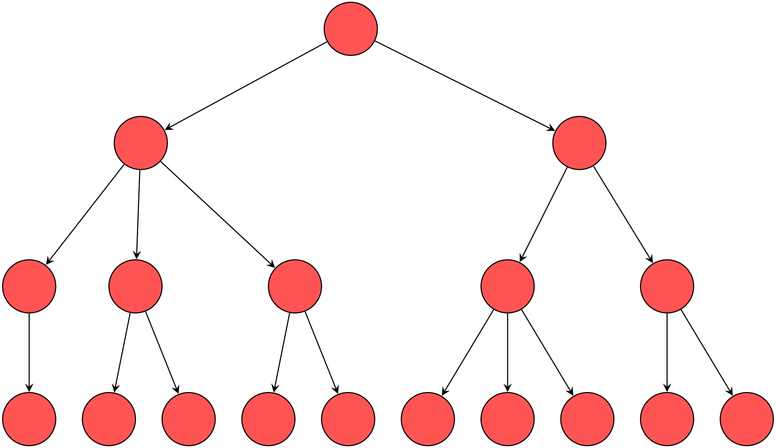

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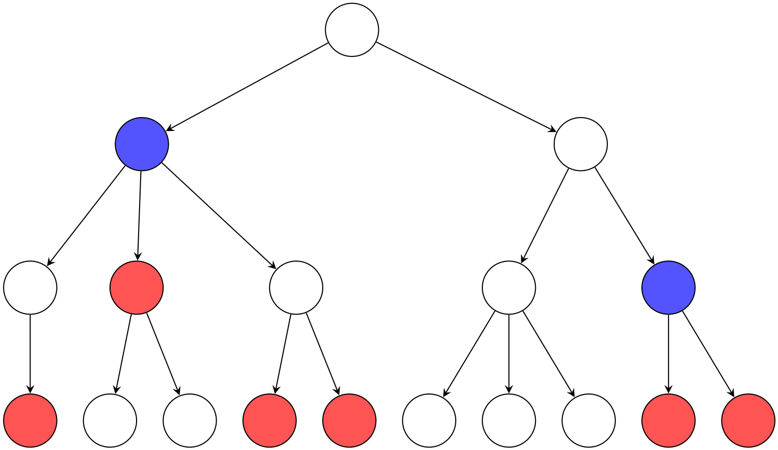
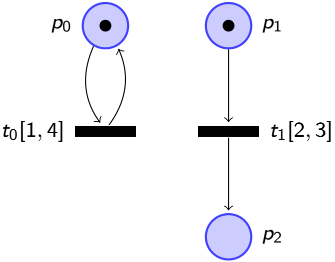


$\varphi \longrightarrow \psi$

State Classes [BD91]

- There is an uncountable number of states even in **bounded** TPNs;
- $\Rightarrow$ group all states obtained by the same sequence of transition firing;



Initially:

$$\begin{cases} 1 \leq t_0 \leq 4 \\ 2 \leq t_1 \leq 3 \end{cases}$$

Fire t_0:

$$\begin{cases} 1 \leq t_0 \leq 4 \\ 2 \leq t_1 \leq 3 \\ \mathbf{t_0 \leq t_1} \end{cases}$$

New times to fire:

$$\begin{cases} 1 \leq t_0 \leq 4 \\ 2 \leq \mathbf{t'_1} + \mathbf{t_0} \leq 3 \\ t_0 \leq \mathbf{t'_1} + \mathbf{t_0} \end{cases}$$

Disabled (incl. t_0):

$$\{ \ \mathbf{0} \leq t'_1 \leq \mathbf{2}$$

Newly enabled:

$$\begin{cases} \mathbf{1 \leq t_0 \leq 4} \\ 0 \leq t_1 \leq 2 \end{cases}$$

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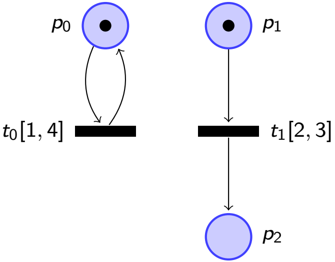

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New times to fire:

$$\begin{cases} 1 \leq t_0 \leq 4 \\ 2 \leq \mathbf{t_1' + t_0} \leq 3 \\ t_0 \leq \mathbf{t_1' + t_0} \end{cases}$$

Disabled (incl. t_0):

$$\{ \ \mathbf{0} \leq t_1' \leq \mathbf{2}$$

Newly enabled:

$$\begin{cases} \mathbf{1 \leq t_0 \leq 4} \\ 0 \leq t_1 \leq 2 \end{cases}$$

Class firing domains are zones (DBMs).

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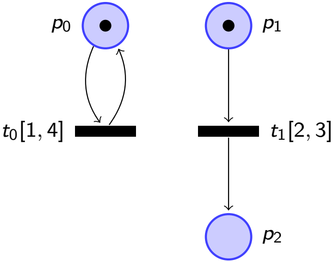

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Newly enabled:

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Class firing domains are zones (DBMs).
Roméo can also do symbolic simulation using zones *à la* Timed Automata.

Conclusion

- Buy Roméo **now**!
  - Roméo allows for a wide range of analyses on Time Petri Nets (extended with variables);
  - The additional combined availability of costs, parameters, and stopwatches make it unique;
  - It is constantly evolving as a prototype but has good performance and not too many bugs.
- **Next** evolutions and uses:
  - Add timed control, à la Uppaal-Tiga, but with state classes;
  - Add lazy abstraction based algorithms [JL16];
  - Model the multicore version of Trampoline RTOS [TBFR17]

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