Model-checking Real-time Systems with Roméo
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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 $\rightarrow$ Petri nets;
- Complex discrete behaviors $\rightarrow$ discrete variables;
- Timing uncertainty $\rightarrow$ time intervals;
- Preemptive scheduling $\rightarrow$ stopwatches;
- Design uncertainty $\rightarrow$ parameters;
- Soft real-time constraints, or energy constraints $\rightarrow$ 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

\[ t_0[1, 4] \rightarrow t_1[2, 3] \]

\[ p_0 \rightarrow p_1 \]

\[ t_0[1, 4] \rightarrow t_1[2, 3] \]

\[ p_2 \]
Time Petri Nets

\[ t_0 \in [1, 4] \]
\[ t_1 \in [2, 3] \]
Time Petri Nets

\[ t_0 \in [1, 4] \rightarrow [0, 2.9] \]
\[ t_1 \in [2, 3] \rightarrow [0.9, 1.9] \]
Time Petri Nets

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

\[ t_0 \rightarrow 0.9 \rightarrow 1.9 \rightarrow [0, 2.9] \quad t_1 \rightarrow [0.9, 1.9] \]
Time Petri Nets

\[
\begin{align*}
\text{t}_0 & \in \left[1, 4\right] & \text{t}_0 & \rightarrow & \left[0, 2.9\right] & \left[0.9, 1.9\right] \\
\text{t}_1 & \in \left[2, 3\right] & \text{t}_1 & \rightarrow & \left[1, 4\right] & \left[0.9, 1.9\right] & \left[0, 0\right]
\end{align*}
\]
Time Petri Nets

\[ p_0 \xrightarrow{t_0 \in [1, 4]} [0, 2.9] \]
\[ t_0 \xrightarrow{t_1 \in [2, 3]} [0.9, 1.9] \]
\[ t_1 \xrightarrow{1.1} [0.9, 1.9] \]

\[ p_1 \xrightarrow{t_0 \in [1, 4]} [0, 2.1] \]
\[ t_0 \xrightarrow{t_1} [0, 2.1] \]

\[ p_2 \xrightarrow{t_1} [0, 2.1] \]
Basic Properties

- **The non-nested** fragment of TCTL + (bounded) **response**;

- **Marking** properties are either:
  - linear constraints on the marking: $p_1 + 2 \times p_2 > 4$
  - a boundedness property: bounded(1)
  - a deadlock property: deadlock

- **Temporal** properties ($\phi, \psi$ are marking properties):
  - $E \phi U [3, 4] \psi$: there is a path on which $\psi$ eventually holds in 3 to 4 t.u. and $\phi$ holds in the meantime;
  - $A \phi U [3, 4] \psi$: on all paths $\psi$ eventually holds in 3 to 4 t.u. and $\phi$ holds in the meantime;
  - $\phi \longrightarrow [0, 5] \psi$: whenever $\phi$ holds, on all subsequent paths $\psi$ holds within 5 t.u.

- **Classic shorthands**:
  - $EF [3, 4] \psi = E \text{true} U [3, 4] \psi$: reachability;
  - $AF [3, 4] \psi = A \text{true} U [3, 4] \psi$: inevitability;
  - $EG \psi = \neg AF (\neg \psi)$: preservability;
  - $AG \psi = \neg EF (\neg \psi)$: safety.
Basic properties
Basic properties
Basic properties
Basic properties

\[ \text{AF}_\varphi \]
Basic properties
Basic properties
Basic properties
State Classes [BD91]

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

New times to fire:

Initially:

\[
\begin{align*}
&1 \leq t_0 \leq 4 \\
&2 \leq t_1 \leq 3
\end{align*}
\]

Fire \(t_0\):

\[
\begin{align*}
&1 \leq t_0 \leq 4 \\
&2 \leq t_1 \leq 3 \\
&t_0 \leq t_1
\end{align*}
\]

Disabled (incl. \(t_0\)):

\[
\begin{align*}
&0 \leq t_1' \leq 2
\end{align*}
\]

Newly enabled:

\[
\begin{align*}
&1 \leq t_0 \leq 4 \\
&0 \leq t_1 \leq 2
\end{align*}
\]
State Classes [BD91]

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

![Petri Net Diagram]

Initially:

\[
\begin{align*}
1 \leq t_0 &\leq 4 \\
2 \leq t_1 &\leq 3
\end{align*}
\]

Fire \( t_0 \):

\[
\begin{align*}
1 \leq t_0 &\leq 4 \\
2 \leq t_1 &\leq 3 \\
t_0 &\leq t_1
\end{align*}
\]

Disabled (incl. \( t_0 \)):

\[
\begin{align*}
0 \leq t'_1 &\leq 2
\end{align*}
\]

Newly enabled:

\[
\begin{align*}
1 \leq t_0 &\leq 4 \\
0 \leq t_1 &\leq 2
\end{align*}
\]

Class firing domains are zones (DBMs).
State Classes [BD91]

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

\[
p_0 \quad t_0[1, 4] \quad p_1 \quad t_1[2, 3] \quad p_2
\]

Initially:
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\begin{align*}
1 & \leq t_0 \leq 4 \\
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Fire \( t_0 \):
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1 & \leq t_0 \leq 4 \\
2 & \leq t_1 \leq 3 \\
t_0 & \leq t_1
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Newly enabled:
\[
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0 & \leq t_1 \leq 2
\end{align*}
\]

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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