mCRL2 toolset January 2009 release

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mCRL2 toolset: analysis of system behaviour

Analysis of system behaviour:

- Modelling: create an *abstract* model of the *behaviour* of the system
  - *gain insight* in the behaviour
  - *reduce complexity* to allow for validation and verification
- Validation: are we building the right product?
  - *test requirements* on the model for a number of paths and configurations
  - *simulate* the model
  - *visualise* the model
- Verification: are we building the product right?
  - *verify requirements* on the model for all possible paths and configurations

mCRL2 toolset: goals

Goals of the mCRL2 toolset:

- Research:
  - Develop *techniques* for the analysis of system behaviour
  - Provide a *generic basis* for the analysis of system behaviour
- Education:
  - Teach model-based design, validation and verification
- Valorisation:
  - *Industrial application* of verification techniques

mCRL2 toolset: overview

Overview of the mCRL2 toolset:

- 20 years of history:
  - Late 1980s: Common Representation Language (CRL)
  - From 1990: μCRL
  - During 1990s: μCRL toolset
  - From 2004: mCRL2 and mCRL2 toolset
- Collection of tools for the analysis of system behaviour
- External languages and tools are supported:
  μCRL, CADP, χ, PNML, TorX, LySa, SystemC, LTSmin
- Multi-platform: Windows, Mac and UNIX variants
- Free software licence: Boost licence
- Release policy: fixed release cycle (January and July)

mCRL2 toolset: January 2009 release

Released on Monday 26th of January, 2009.

Most important *improvements*:

- Exact rational numbers
- Unique representations of finite sets and bags
- Improved visualisation of directed graphs
- Distributed state space generation

New *experimental* tools (not available by default):

- Elimination of real numbers
- Graphical specification of behaviour
- Optimisation of Parameterised Boolean Equation Systems

Exact rational numbers

Rational numbers in mCRL2:

- New operations: $/$, $floor$, $ceil$, $round$
- No limitations on size

A process that divides by 2... 500 times:

act report:$\mathbb{R}$;
error;

proc $\mathsf{P}(n{:}\mathbb{N}, r{:}\mathbb{R}) = (n < 500) \rightarrow \mathsf{report}(r) \cdot \mathsf{P}(n+1, r/2)$
$+ \ (r/2 \geq r) \ \rightarrow \mathsf{error} \cdot \delta;$

init $\mathsf{P}(0, 1);$

State space generation:

- State space: 501 states and 500 transitions
- No error actions are found

Unique representations of finite sets

The wolf, the goat, and the cabbage:

Unique representations of finite sets

The wolf, the goat, and the cabbage:

Data type declarations:

sort $Item = \mathbf{struct}\ wolf \mid goat \mid cabbage;$
$Position = \mathbf{struct}\ left \mid right;$
$Shores = \mathbf{struct}\ shores(Set(Item), Set(Item));$

map $opp : Position \to Position;$
$items : Shores \times Position \to Set(Item);$
$update : Shores \times Position \times Item \to Shores;$

Unique representations of finite sets

The wolf, the goat, and the cabbage:

Data type definitions:

var $s, t : Set(Item); i : Item;$

eqn $opp(left) = right;$
$opp(right) = left;$
$items(shores(s, t), left) = s;$
$items(shores(s, t), right) = t;$
$update(shores(s, t), right, i) = shores(s \setminus \{i\}, t \cup \{i\});$
$update(shores(s, t), left, i) = shores(s \cup \{i\}, t \setminus \{i\});$

Unique representations of finite sets

The wolf, the goat, and the cabbage:

Actions:

act is_eaten:$Item$;
move:$Position$;
move:$Position \times Item$;
done;

Unique representations of finite sets

The wolf, the goat, and the cabbage:

Process:

$$
\begin{aligned}
\textbf{proc}\quad & \mathsf{WGC}(s{:}Shores, p{:}Position) = \\
& \quad (\{wolf, goat\} \subseteq items(s, opp(p))) \rightarrow \mathsf{is\_eaten}(goat) \cdot \delta \\
& + (\{goat, cabbage\} \subseteq items(s, opp(p))) \rightarrow \mathsf{is\_eaten}(cabbage) \cdot \delta \\
& + (\{wolf, goat\} \not\subseteq items(s, opp(p)) \wedge \{goat, cabbage\} \not\subseteq items(s, opp(p))) \rightarrow \\
& \quad (\mathsf{move}(opp(p)) \cdot \mathsf{WGC}(s, opp(p)) \\
& \qquad + \sum_{i:Item} (i \in items(s, p)) \rightarrow \\
& \qquad\quad \mathsf{move}(opp(p), i) \cdot \mathsf{WGC}(update(s, opp(p), i), opp(p)) \\
& \qquad + (items(s, right) \approx \{wolf, goat, cabbage\}) \rightarrow \mathsf{done} \\
& \quad); \\
\textbf{init}\quad & \mathsf{WGC}(shores(\{wolf, goat, cabbage\}, \emptyset), left);
\end{aligned}
$$

Unique representations of finite sets

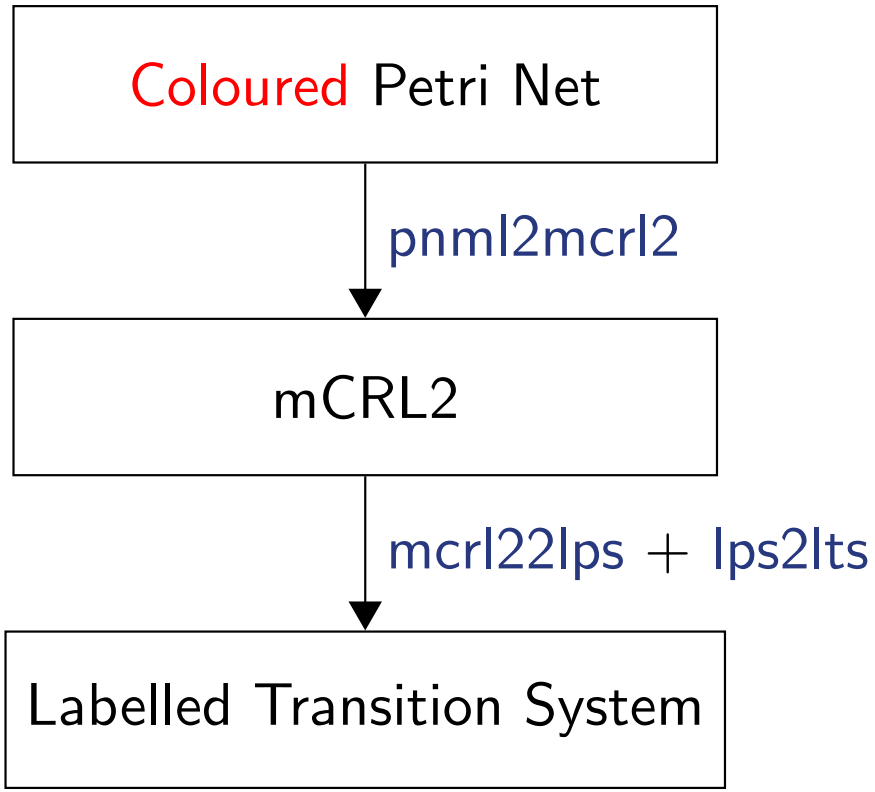
The wolf, the goat, and the cabbage:

State space generation:

- State space: 19 states and 44 transitions
- The following shortest solution is found:

move$(right, goat)$
move$(left)$
move$(right, wolf)$
move$(left, goat)$
move$(right, cabbage)$
move$(left)$
move$(right, goat)$
done

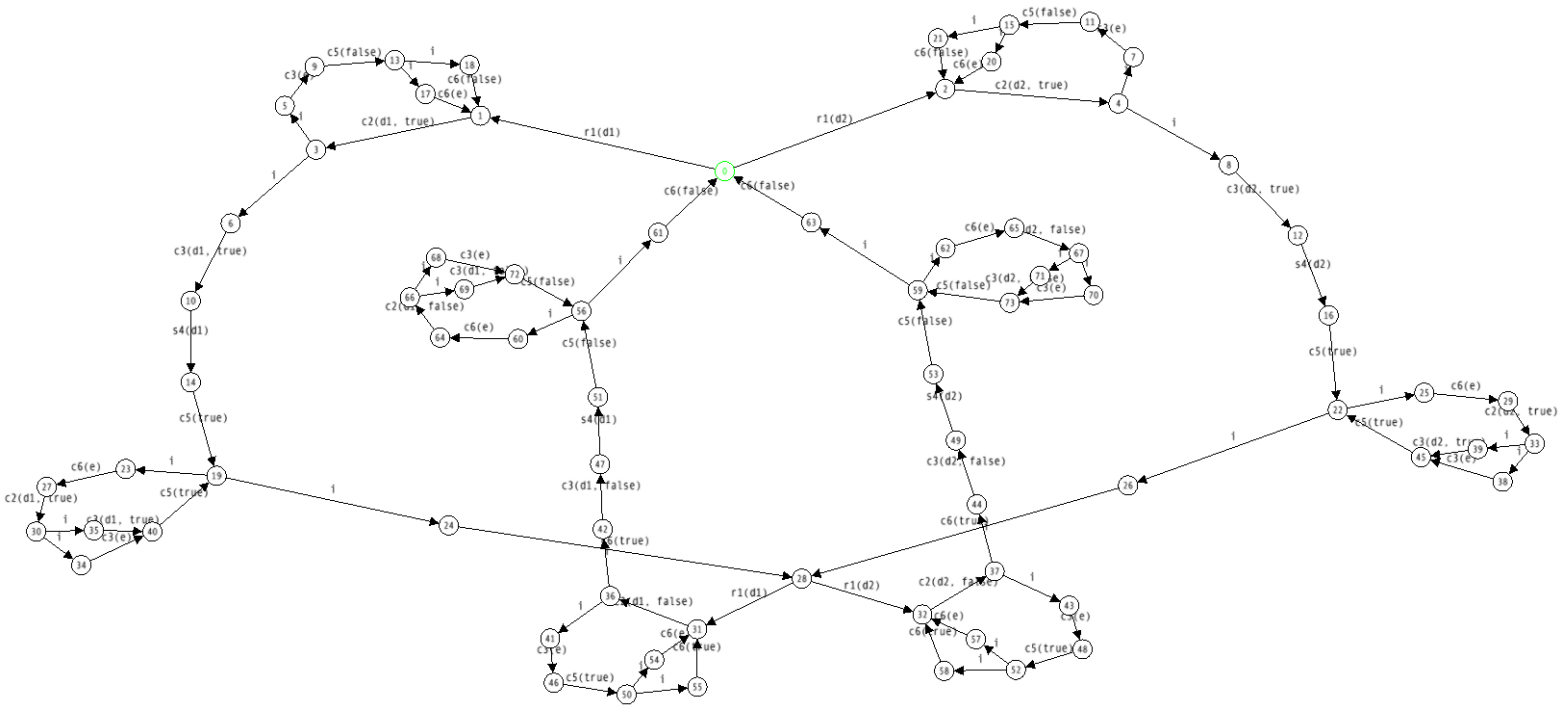
Unique representations of finite bags



Improved visualisation of directed graphs

Improvements of ltsgraph:

- OpenGL implementation
- dot file support



Distributed state space generation

Compatibility with the LTSmin toolset:

- Developed at the Formal Methods & Tools group, University of Twente
- Implements latest techniques for distributed instantiation of labelled transition systems
- Tools for mCRL2 state space generation:
  - Sequential: lps2lts-grey
  - Symbolic: lpsreach
  - Distributed: lps2lts-mpi
  - mCRL2 libraries provide next state/transition functionality

Elimination of real numbers (experimental)

A timed light switch:

$$
\begin{array}{ll}
\textbf{sort} & Light = \textbf{struct}\ off \mid on \mid bright; \\
\textbf{act} & \mathsf{press}, \mathsf{status}{:}Light; \\
\textbf{proc} & \mathsf{P}(r{:}\mathbb{R}, l{:}Light) = \\
 & \quad (l \approx off) \rightarrow \mathsf{press}(on) \cdot \mathsf{P}(0, on) \\
 & + \sum_{s:\mathbb{R}} (l \not\approx off \wedge 0 < s \wedge r + s < 5) \rightarrow \mathsf{press}(bright) \cdot \mathsf{P}(r + s, bright) \\
 & + \sum_{s:\mathbb{R}} (l \not\approx off \wedge 0 < s \wedge r + s \geq 5) \rightarrow \mathsf{press}(off) \cdot \mathsf{P}(0, off) \\
 & + \mathsf{status}(l) \cdot \mathsf{P}(r, l); \\
\textbf{init} & \mathsf{P}(0, off);
\end{array}
$$

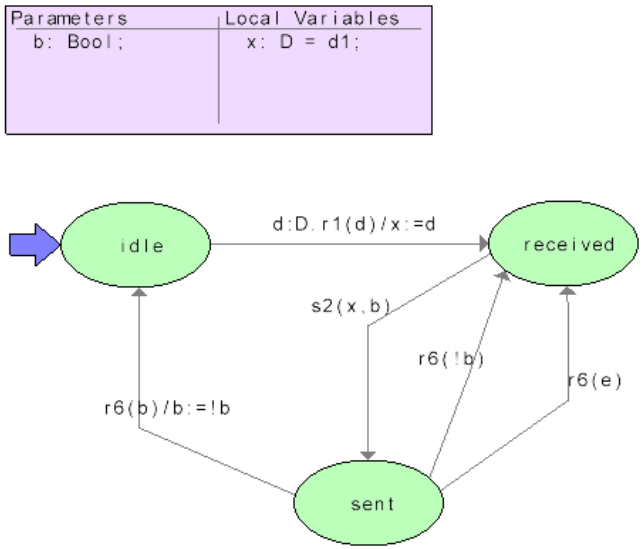
State space generation:

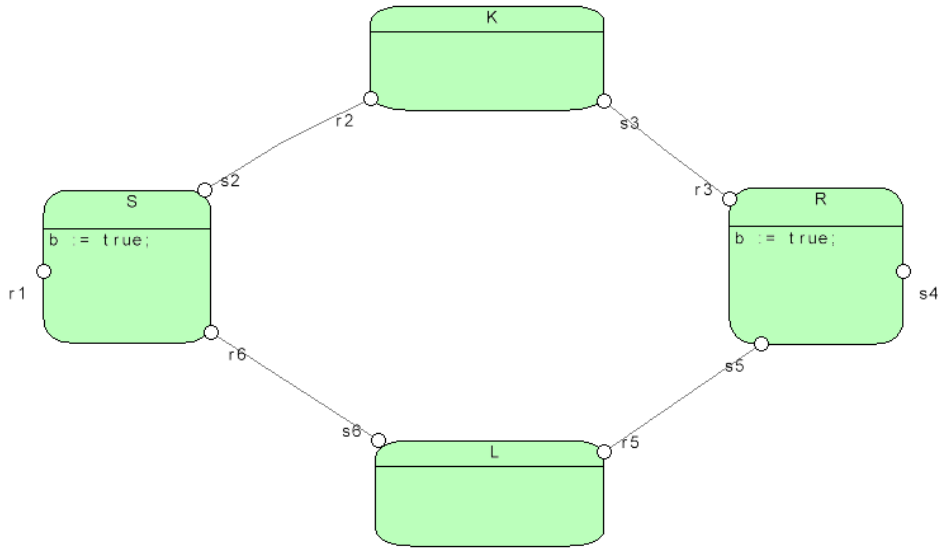
- Impossible directly
- Possible using lpsrealelm: 3 states and 8 transitions

Graphical modelling (experimental)

Graphical Process Editor (GraPE):

- graphical specification of sequential behaviour
- graphical specification of parallel behaviour





Thank you for your attention

More information can be found on `mcrl2.org`.