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Lifted Model Checking for Relational MDPs (PCTL-REBEL)

PROBLEM STATEMENT

Given

a Relational MDP M (can be infinitely large) and a pCTL property ϕ

Find

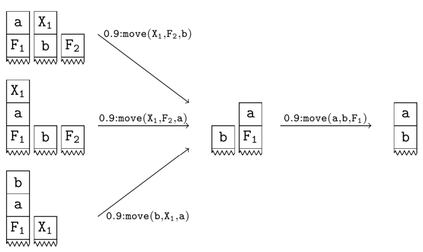
all (infinitely many) states in the RMDP that satisfy the property

CONTRIBUTIONS

- A framework for Lifted Model Checking in relational domains
- Lifting: works at a more abstract relational level where variables are only instantiated when needed
- An implementation that outperforms state-of-the-art model checkers in relational domains
- A theoretical proof that pCTL model checking is decidable for relational MDPs that have a infinite domain, provided that the states have a bounded size

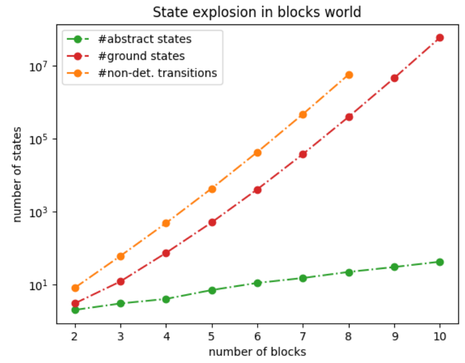
REBEL

Relational Bellman Operator for Logical Regression



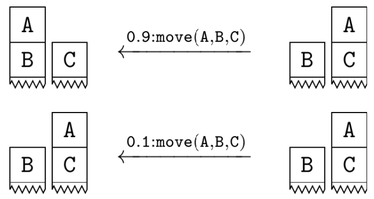
WHY? SCALABILITY

Blocks World. Number of blocks grows ⇒ Number of ground states explodes. However, the number of abstract states is more resilient.



INGREDIENTS

- **Relational MDP** uses variables to compactly represent a ground MDP $\langle S, A, T \rangle$.



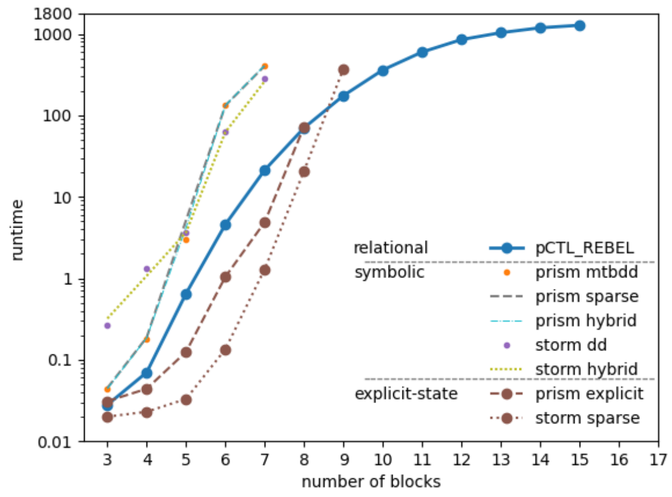
- **PCTL** (Probabilistic Computational Tree Logic) E.g. The machine gives a warning before shutting down with a probability higher than 0.95.

$$\textit{state formula } \phi ::= \texttt{true} \mid l \mid \neg l \mid \phi \wedge \phi \mid \mathrm{P}_{\bowtie \mathrm{p}}[\psi]$$
$$\textit{path formula } \psi ::= \mathrm{X}\ \phi \mid \phi\ \mathrm{U}^{\leq \mathrm{k}}\ \phi \mid \phi\ \mathrm{U}\ \phi$$

where l is an atom (that can contain variables), p is a probability and that $0 \leq \mathrm{p} \leq 1$, $\mathrm{k} \in \mathbb{N}$ is a step bound and $\bowtie \in \{\leq, <, \geq, >\}$.

RESULTS

- We compare to Symbolic Model Checking and other state-of-the-art model checkers PRISM and STORM
- $\mathrm{P}_{\geq 0.5}[\mathrm{F}^{\leq 10}\mathrm{on(a, b)}]$
- Lifted Model Checking> Explicit State > Symbolic Model Checking
- PRISM handles at most 8 blocks (3.9e5 states)
- STORM handles at most 9 blocks (4.6e5 states)
- PCTL-REBEL handles at most 15 blocks (6.5e13 states)



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