Constrained and Robust Policy Synthesis with Satisfiability-Modulo-Probabilistic-Model-Checking

Linus Heck, **Filip Macák**, Milan Češka, Sebastian Junges

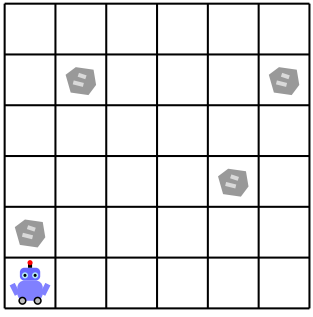
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Introduction



Grid where robot slips to the left with probability 0.1

Goal: Find a robot policy that collects all rocks with probability ≥ 0.9:

- Wherever the rocks are (robust)
- With a simple set of rules (constrained)

Previous work has been unable to find a robot policy that always works.

At the end of this talk, we will see how we can solve this!

Challenges and Approach

Challenge: Combinatorial search space and uncertainty

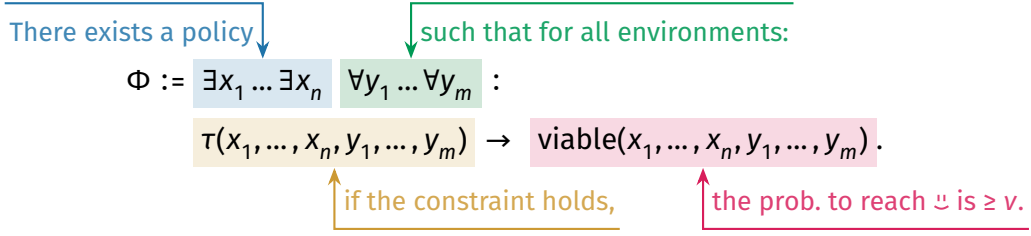
- Monolithic encodings (e.g. MILPs): Slow at evaluating MDP policies
- Abstraction-Refinement (e.g. Branch&Bound): Cannot reason about arbitrary constraints

Our approach: SMT Solving + Probabilistic Model Checking (SMPMC)

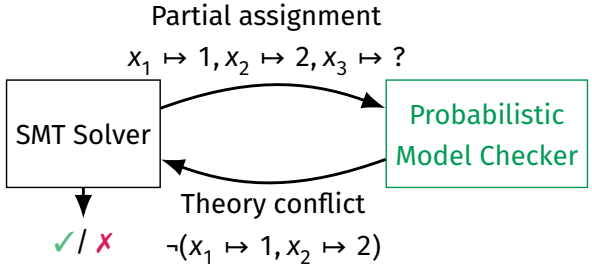
- Search space and constraints: handled by the SMT solver
- Solving underlying MDPs: handled by the probabilistic model checker (e.g. using value iteration)

SMT Problem Formulation

Input formula to SMT solver:



SMT Solving Meets Probabilistic Model Checking



- Smarter than Guess-And-Check: Check partial assignments, prune early
- More flexible than Abstraction-Refinement: SMT solver handles search space

Experiments

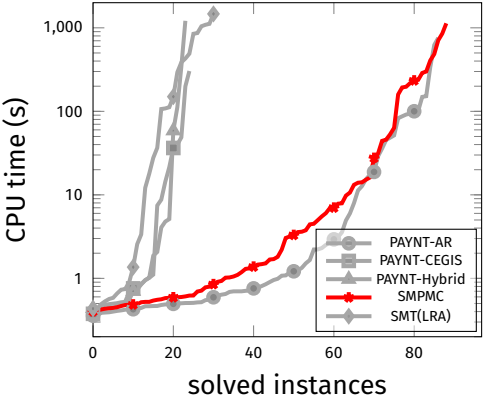
- 372 benchmarks from different domains: Sets of MCs, POMDPs with FSCs, Multi-Environment MDPs
- Comparisons: PAYNT (state-of-the-art for policy synthesis), monolithic SMT (baseline)

Q1: Is SMPMC competitive with the comparisons at policy synthesis?

Q2: Can SMPMC handle both robustness and arbitrary constraints?

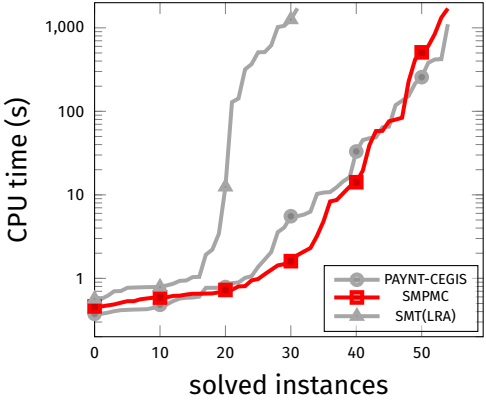
Results: Comparisons Against Baselines

Unconstrained synthesis (single env.):



⇒ competitive with AR!

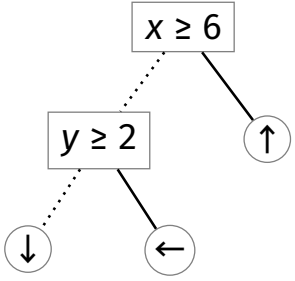
Constrained synthesis (single env.):

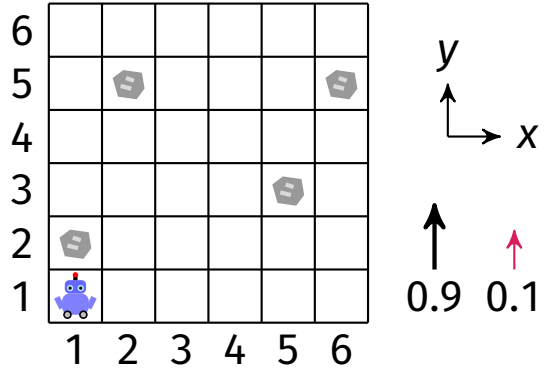


⇒ competitive with Guess-And-Check!

Solving Rocks with Constrained and Robust Synthesis

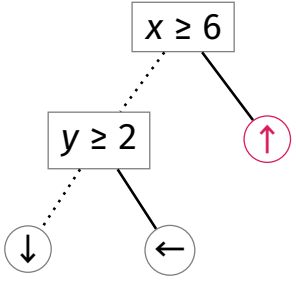
SMPMC finds a five-node decision tree that picks up all rocks in a spiral:

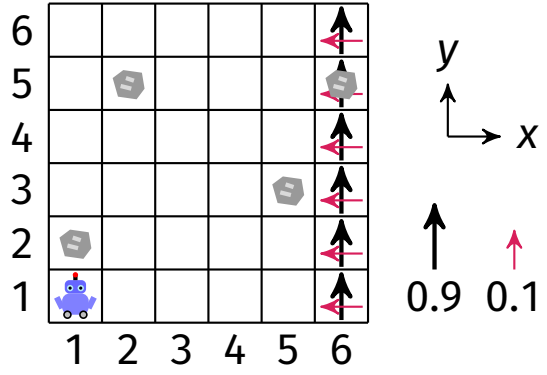




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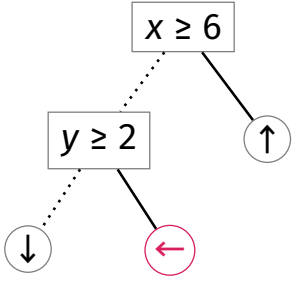
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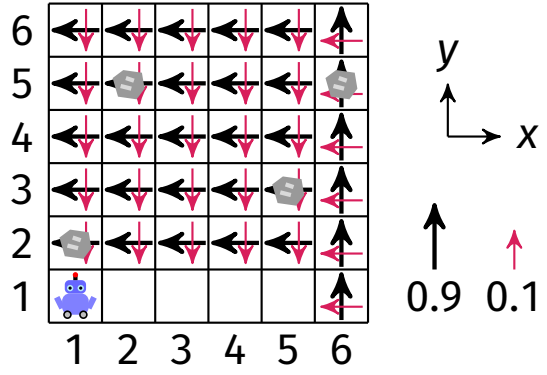




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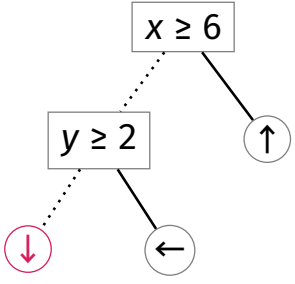
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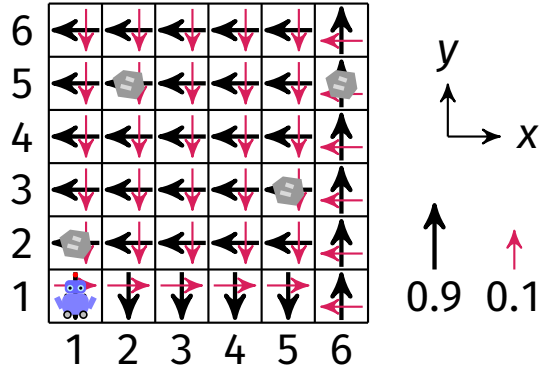




Solving Rocks with Constrained and Robust Synthesis

SMPMC finds a five-node decision tree that picks up all rocks in a spiral:





Contributions

- SMPMC: A novel, versatile, and efficient approach that tightly integrates satisfiability solvers with probabilistic model checking
- First effective approach that constructs robust decision tree policies
- Competitive with state-of-the-art heuristics, solves new problems



