Abstractions for Planning with State-Dependent Action Costs

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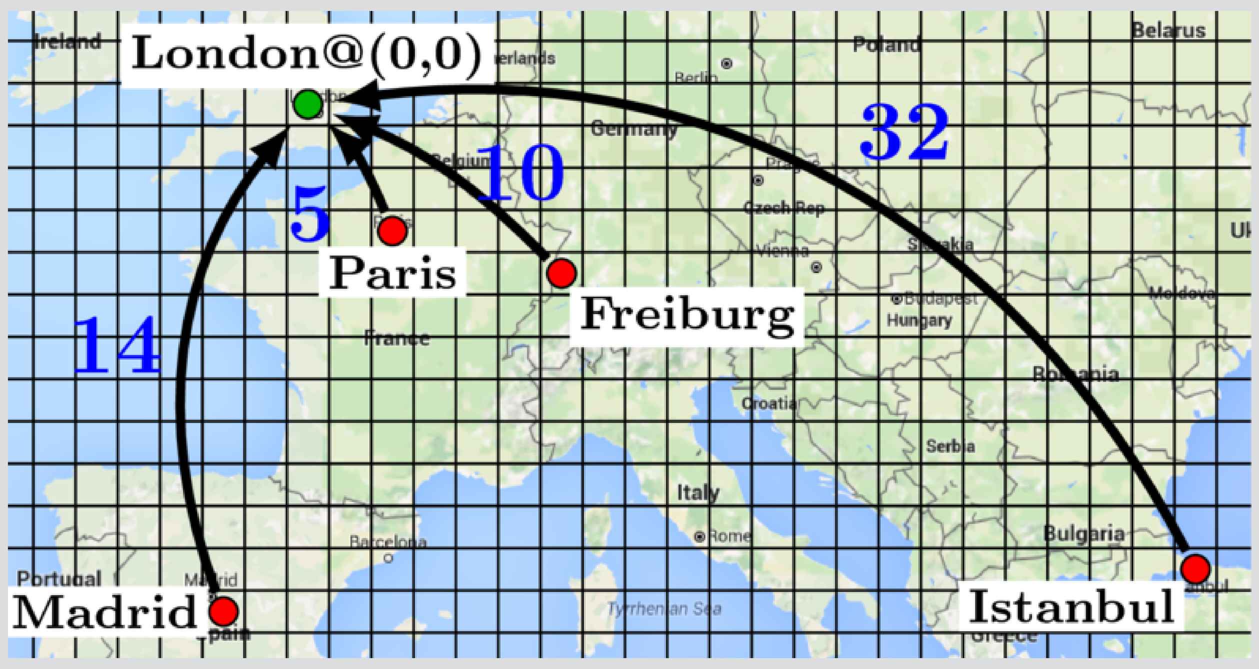
What are State-Dependent Action Costs?



$$cost(flyTo(London)) = |x_{\text{current}}| + |y_{\text{current}}|.$$

Advantages:

- Structured and "natural"
- Exponentially more compact, fewer redundancies
- Relevant to applications

Edge-Valued Multi-Valued Decision Diagrams

Example: Decision diagram for function

$cost_a = xy^2 + z + 2.$

$\mathcal{D}_x = \mathcal{D}_z = \{0, 1\}, \mathcal{D}_y = \{0, 1, 2\}.$

E.g., $cost_a(1, 2, 0) = 2 + 0 + 4 + 0 = 6.$

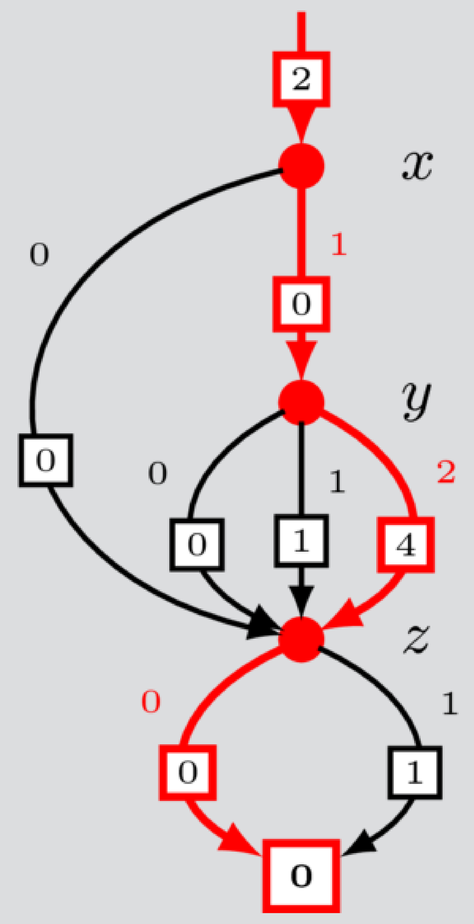
Advantages:

- Follow naturally from desired properties
- Exhibit additive structure
- Attribute partial costs to facts responsible for them
- Often compact

Properties:

- ✔ Existence
- ✔ Uniqueness (if reduced and ordered)
- ✔ Basic arithmetic operations supported

[Lai et al, 1996; Ciardo & Siminiceanu, 2002]

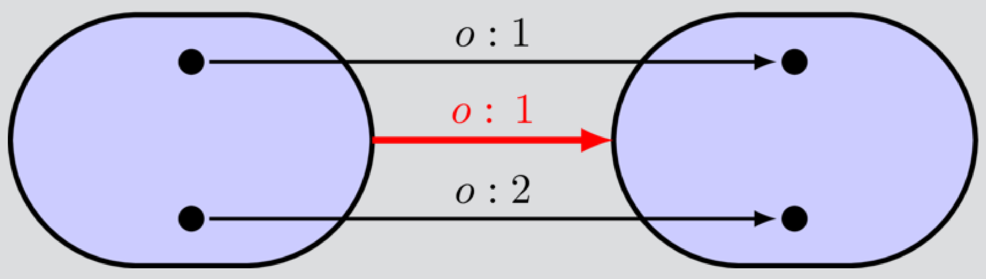


Abstraction Heuristics

Abstract Costs

Optimal planning with SDAC
⇝ admissible abstraction heuristics

Minimize concrete costs!



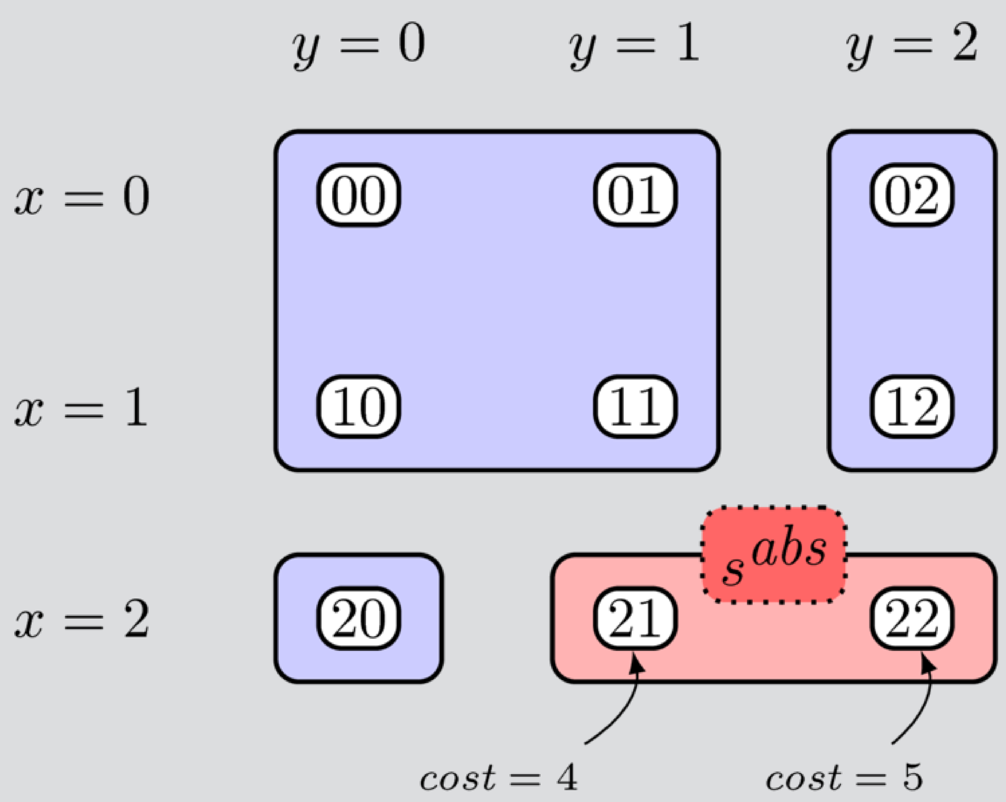
Problem: exponentially many concrete states

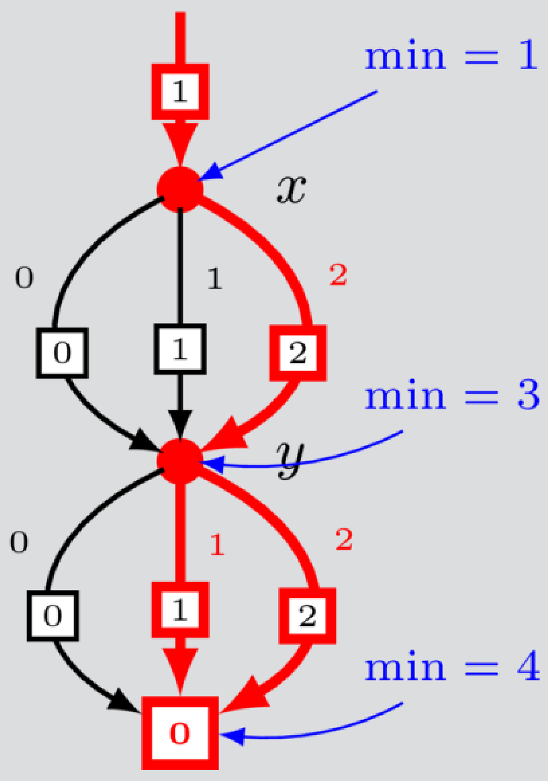
Aim: Efficient computation

Cartesian Abstraction

Def.: A set of states s^{abs} is Cartesian if it is of the form $D_1 \times \cdots \times D_n$, where $D_i \subseteq \mathcal{D}_i$ for all $i = 1, \ldots, n$. An abstraction is Cartesian if all its abstract states are Cartesian sets.

[Ball et al., 2001; Seipp & Helmert, 2013]



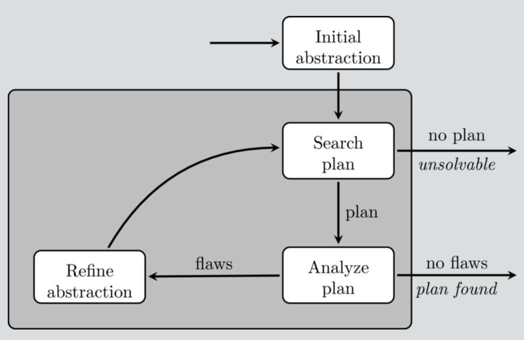


Theorem: For Cartesian abstractions, a top-sort traversal of the cost EVMDD with local minimizations over those edges consistent with the abstract state correctly computes abstract costs.

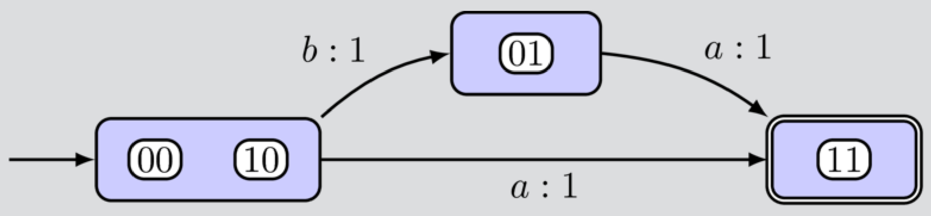
Counterexample-Guided Abstraction Refinement

How to find Cartesian abstractions?

⇝ Counterexample-Guided Abstraction Refinement (CEGAR)



Usual flaws, plus cost-mismatch flaw: action more costly in concrete state than in abstract state. Ex.:

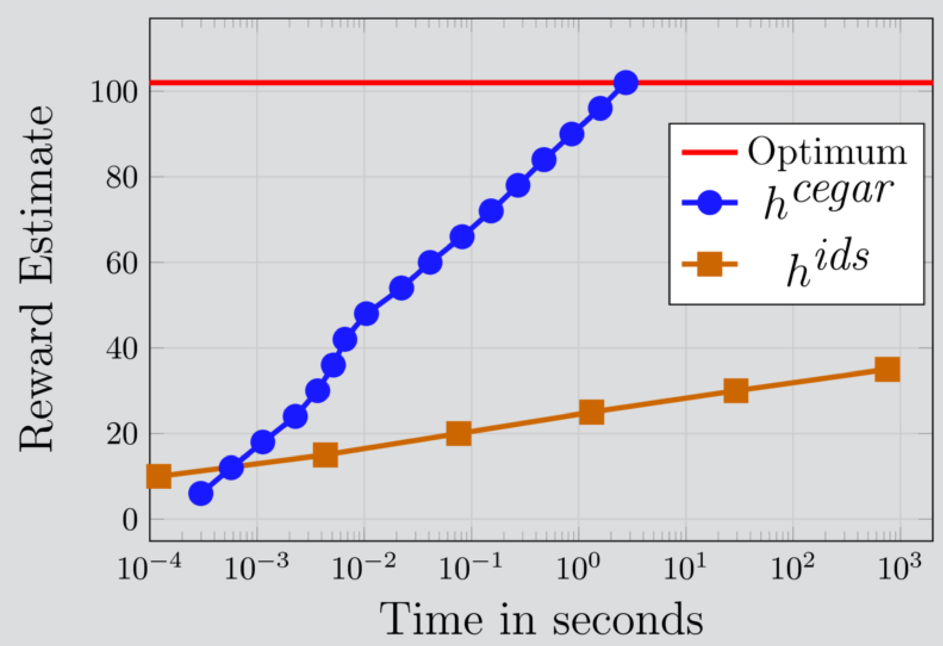


$a = \langle \top, \quad x \wedge y \rangle, \quad cost_a = 2x + 1 \qquad s_0 = 10$
$b = \langle \top, \ \neg x \wedge y \rangle, \quad cost_b = 1 \qquad s_\star = x \wedge y$

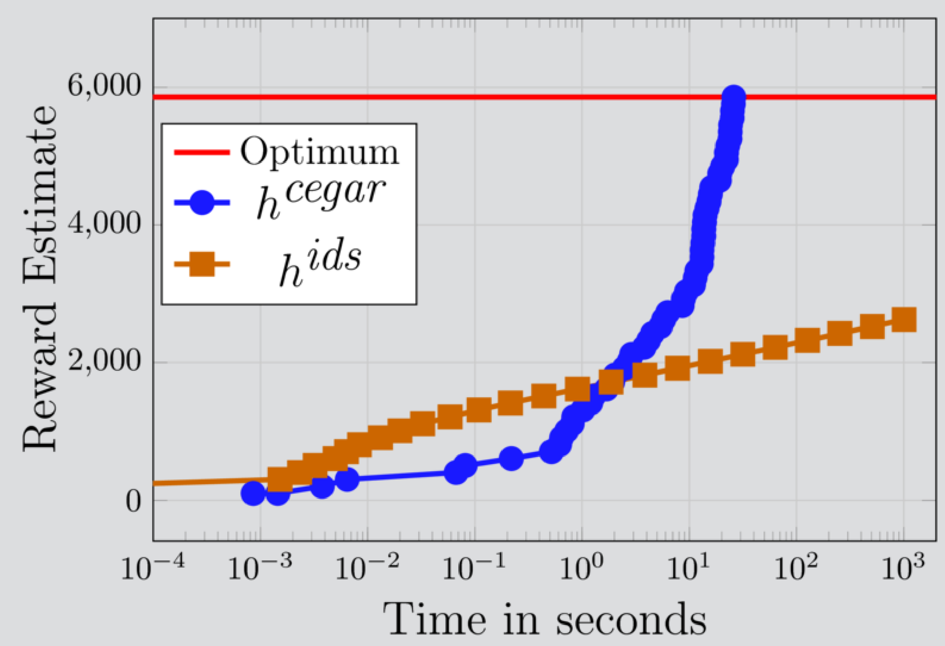
- Optimal abstract plan: a (abstract cost 1)
- This is also a concrete plan (concrete cost 3)
- Optimal concrete plan: b, a (conc. and abst. cost 2)

Experiments

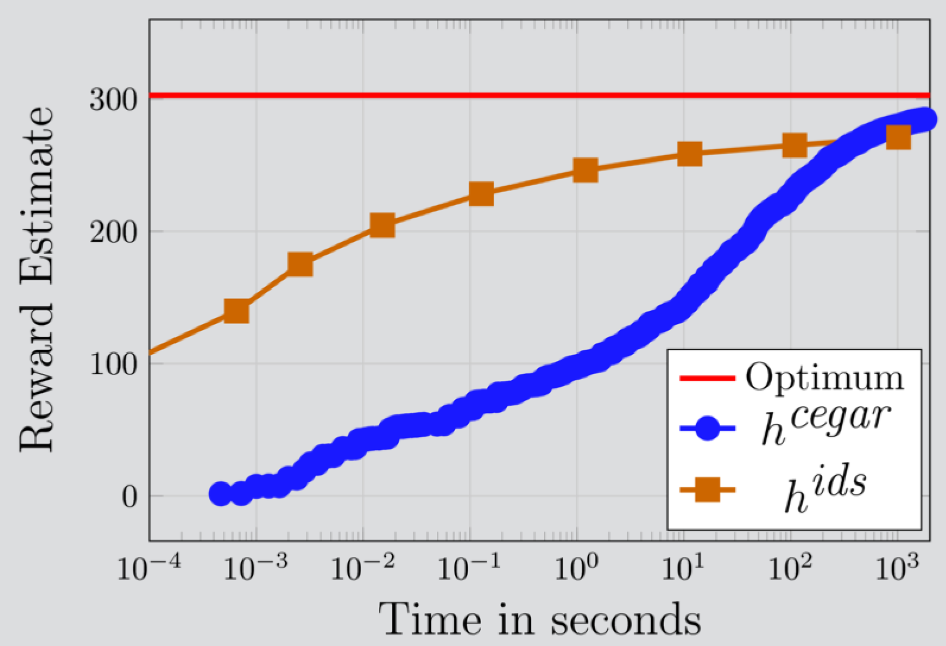
Academic Advising



Triangle Tireworld



Tamarisk



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