Symbolic Planning with EVMDDs

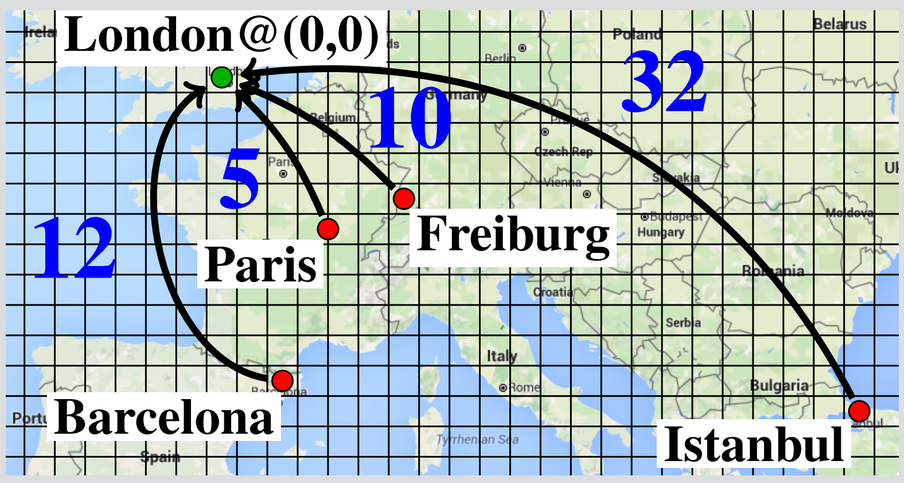
David Speck, Florian Geißer and Robert Mattmüller

University of Freiburg

State-Dependent Action Costs (SDAC)

- Classical Planning with state dependent costs
- $c_a : \mathcal{S} \to \mathbb{N}$ is the *cost function* of action a

Travelling Salesman Problem

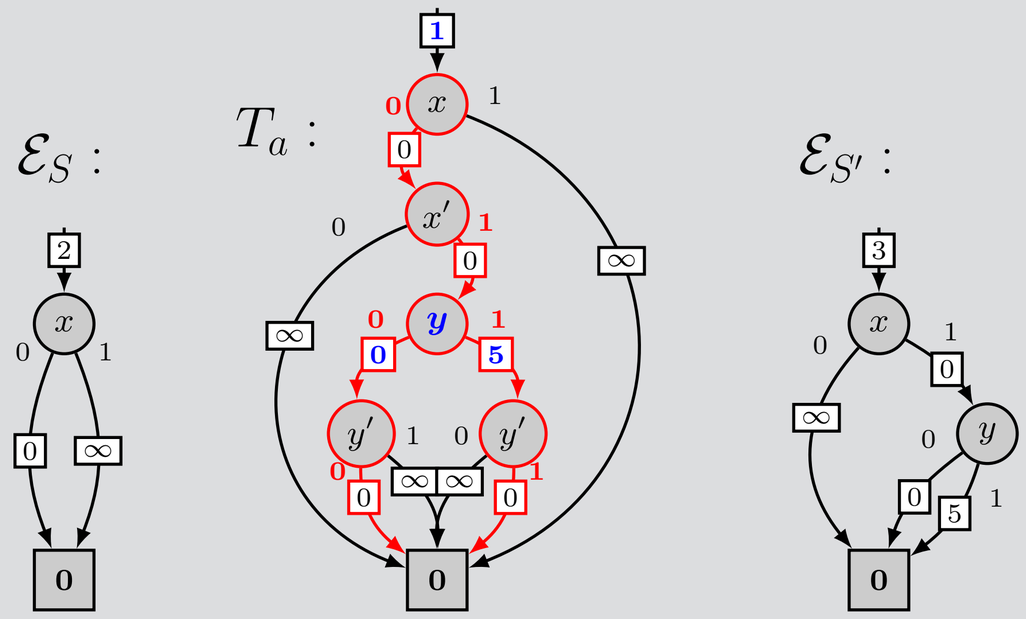


Action flyLondon:

- $flyLondon = \langle \top, x_{\text{cur}} := \overbrace{x_{\text{London}}}^{=0} \wedge y_{\text{cur}} := \overbrace{y_{\text{London}}}^{=0} \wedge \ldots \rangle$
- $c_{flyLondon} = |\underbrace{x_{\text{London}}}_{=0} - x_{\text{cur}}| + |\underbrace{y_{\text{London}}}_{=0} - y_{\text{cur}}|$

States and Actions

$$S \longrightarrow \boxed{\begin{array}{c} a = \langle x \doteq 0, x \doteq 1 \rangle \\ c_a = 5y + 1 \end{array}} \longrightarrow S'$$



State S:

- $S = \{s | s(x) = 0\}$
- $c(\{x \doteq 0, y \doteq 0\}) = 2$
- $c(\{x \doteq 0, y \doteq 1\}) = 2$

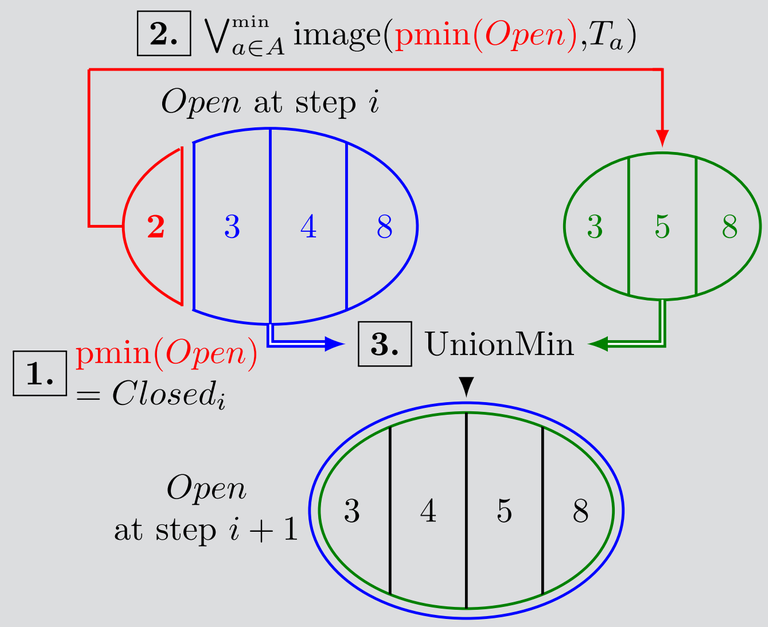
State S′:

- $S' = \{s | s(x) = 1\}$
- $c(\{x \doteq 1, y \doteq 0\}) = 3$
- $c(\{x \doteq 1, y \doteq 1\}) = 8$

Symbolic Planning

- Operations on sets of states $S \subseteq \mathcal{S}$
- $S \subseteq \mathcal{S}$ represented by *characteristic function* χ_S
- Manipulating $S \triangleq$ Transforming χ_S
  - e.g. $S \cap S' \triangleq \chi_S \wedge \chi_{S'}$
- Actions represented by transition relations

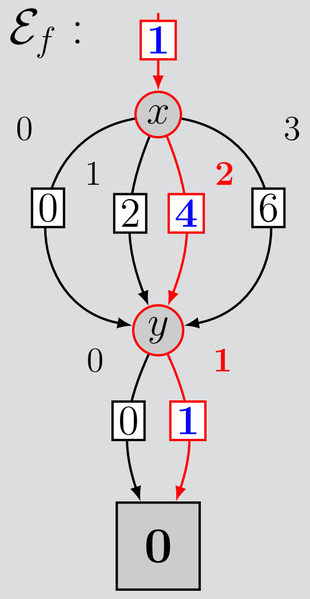
EVMDD-A*



1. Extract states with minimal costs
2. Generate successor states with costs
3. Update open list

Edge-Valued Multi-Valued Decision Diagrams (EVMDDs)

- A possible symbolic representation of state sets and transition relations are EVMDDs



General:

- $\mathcal{S} \to \mathbb{N} \cup \{\infty\}$
- Directed acyclic graph

Example EVMDD $\mathcal{E}_f$:

- $f(x, y) = 2x + y + 1$
- $\mathcal{D}_x = \{0, 1, 2, 3\}$
- $\mathcal{D}_y = \{0, 1\}$
- Evaluation ($x = 2$ & $y = 1$) :
  - $f(\mathbf{2}, \mathbf{1}) = \mathbf{1} + \mathbf{4} + \mathbf{1} = \mathbf{6}$

Idea:

- Encode **cost** and **reachability** with one EVMDD
- Unreachable states are mapped to ∞ (cost)

Experiments + Conclusion

IPC 2014	$A^\star_{\text{blind}}$	$A^\star_{\text{lmcut}}$	SYMBA	**SYMPLE**
COV.(256)	67	86	**153**	90

SDAC	$A^\star_{\text{blind}}$	SYMBA-exp	SYMBA-cost	**SYMPLE**
COV. (206)	92	86	115	**143**

- SYMPLE performs bidirectional EVMDD-A*
- Outperforms other approaches regarding SDAC