Principles of AI Planning

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Winter Semester 2017/2018

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Exercise Sheet 13

Due: Friday, February 2nd, 2018

Exercise 13.1 (Strong stubborn sets, 1+3 points)

Consider the SAS$^+$ planning task Π with variables $V = \{\mathit{pos}, \mathit{left}, \mathit{right}, \mathit{hat}\}$, $\mathcal{D}_{\mathit{pos}} = \{\mathit{home}, \mathit{uni}\}$ and $\mathcal{D}_{\mathit{left}} = \mathcal{D}_{\mathit{right}} = \mathcal{D}_{\mathit{hat}} = \{t, f\}$. The initial state is $I = \{\mathit{pos} \mapsto \mathit{home}, \mathit{left} \mapsto f, \mathit{right} \mapsto f, \mathit{hat} \mapsto f\}$ and the goal specification is $\gamma = \{\mathit{pos} \mapsto \mathit{uni}\}$. There are four operators in O, namely

$$\begin{aligned}
\mathit{put\text{-}on\text{-}left\text{-}shoe} &= \langle \mathit{pos} = \mathit{home} \wedge \mathit{left} = f, \mathit{left} := t\rangle, \\
\mathit{put\text{-}on\text{-}right\text{-}shoe} &= \langle \mathit{pos} = \mathit{home} \wedge \mathit{right} = f, \mathit{right} := t\rangle, \\
\mathit{put\text{-}on\text{-}hat} &= \langle \mathit{pos} = \mathit{home} \wedge \mathit{hat} = f, \mathit{hat} := t\rangle, \text{ and} \\
\mathit{go\text{-}to\text{-}university} &= \langle \mathit{pos} = \mathit{home} \wedge \mathit{left} = t \wedge \mathit{right} = t, \mathit{pos} := \mathit{uni}\rangle.
\end{aligned}$$

(a) Draw the breadth-first search graph (with duplicate detection) for planning task Π without any form of partial-order reduction.

(b) Draw the breadth-first search graph (with duplicate detection) for planning task Π using strong stubborn set pruning. For each expansion of a node for a state s, specify in detail how T_s (and thus $T_{\mathit{app}(s)}$) are computed, i.e., explain how the initial disjunctive action landmark is chosen and how operators are iteratively added to T_s as part of necessary enabling sets or interfering operators, respectively. Break ties in favor of *put-on-left-shoe* over *put-on-right-shoe*.

How many node expansion do you save with strong stubborn sets compared to plain breadth-first search? What about the lengths of the resulting solutions?

You may abbreviate the operator names, state descriptions etc. appropriately.

Exercise 13.2 (Weak vs. strong stubborn sets, 6 points)

Show that *weak* stubborn sets admit exponentially more pruning than *strong* stubborn sets.

Hint: Consider the family of planning tasks $(\Pi_n)_{n\in\mathbb{N}}$, where $\Pi_n = \langle V_n, I_n, O_n, \gamma\rangle$ is the planning task with the following components:

- $V_n = \{a, x, y, b_1, \dots, b_n\}$ with variable domains $\mathcal{D}_a = \mathcal{D}_x = \mathcal{D}_y = \{0, 1\}$ and $\mathcal{D}_{b_i} = \{0, 1, 2\}$ for all $i \in \{1, \dots, n\}$
- $O_n = \{o, o', o_d, \overline{o_d}, o_1, \dots, o_n, \overline{o_1}, \dots, \overline{o_n}\}$
- $\mathit{pre}(o) = \{a \mapsto 0\}$, $\mathit{eff}(o) = \{x \mapsto 1\}$
- $\mathit{pre}(o') = \{a \mapsto 0\}$, $\mathit{eff}(o') = \{y \mapsto 1\}$
- $\mathit{pre}(o_d) = \{a \mapsto 0\}$, $\mathit{eff}(o_d) = \{a \mapsto 1, b_1 \mapsto 1, \dots, b_n \mapsto 1\}$
- $\mathit{pre}(\overline{o_d}) = \{a \mapsto 1\}$, $\mathit{eff}(\overline{o_d}) = \{a \mapsto 0, b_1 \mapsto 1, \dots, b_n \mapsto 1\}$
- $\mathit{pre}(o_i) = \{b_i \mapsto 1\}$, $\mathit{eff}(o_i) = \{b_i \mapsto 2\}$ for $1 \leq i \leq n$
- $\mathit{pre}(\overline{o_i}) = \{b_i \mapsto 2\}$, $\mathit{eff}(\overline{o_i}) = \{b_i \mapsto 1\}$ for $1 \leq i \leq n$
- $I_n = \{a \mapsto 0, x \mapsto 0, y \mapsto 0, b_1 \mapsto 0, \dots, b_n \mapsto 0\}$
- $\gamma = \{x \mapsto 1, y \mapsto 1\}$

You may and should solve the exercise sheets in groups of two. Please state both names on your solution.