Principles of AI Planning

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Winter Semester 2015/2016

Exercise Sheet 11

Due: Friday, January 22nd, 2016

Exercise 11.1 (Strong stubborn sets, 1+3 points)
Consider the SAS+ planning task \( \Pi \) with variables \( V = \{ \text{pos}, \text{left}, \text{right}, \text{hat} \} \), \( D_{\text{pos}} = \{ \text{home}, \text{uni} \} \) and \( D_{\text{left}} = D_{\text{right}} = D_{\text{hat}} = \{ t, f \} \). The initial state is \( I = \{ \text{pos} \rightarrow \text{home}, \text{left} \rightarrow f, \text{right} \rightarrow f, \text{hat} \rightarrow f \} \) and the goal specification is \( \gamma = \{ \text{pos} \rightarrow \text{uni} \} \). There are four operators in \( O \), namely

- \( \text{wear-left-shoe} = \langle \text{pos} \rightarrow \text{home} \land \text{left} = f, \text{left} := t \rangle \),
- \( \text{wear-right-shoe} = \langle \text{pos} \rightarrow \text{home} \land \text{right} = f, \text{right} := t \rangle \),
- \( \text{wear-hat} = \langle \text{pos} \rightarrow \text{home} \land \text{hat} = f, \text{hat} := t \rangle \), and
- \( \text{go-to-university} = \langle \text{pos} \rightarrow \text{home} \land \text{left} = t \land \text{right} = t, \text{pos} := \text{uni} \rangle \).

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

(b) Draw the breadth-first search graph (with duplicate detection) for planning task \( \Pi \) using strong stubborn set pruning. For each expansion of a node for a state \( s \), specify in detail how \( T_s \) (and thus \( T_{\text{app}(s)} \)) 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 \( \text{wear-left-shoe} \) over \( \text{wear-right-shoe} \).

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 11.2 (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 \( \Pi_n = (V_n, I_n, O_n, \gamma) \) is the planning task with the following components:

- \( V_n = \{ a, x, y, b_1, \ldots, b_n \} \) with variable domains \( D_a = D_x = D_y = \{ 0, 1 \} \) and \( D_{b_i} = \{ 0, 1, 2 \} \) for all \( i \in \{ 1, \ldots, n \} \)
- \( O_n = \{ o, o_d, o_t, o_1, \ldots, o_n, o_t, \ldots, o_t \} \)
- \( \text{pre}(o) = \{ a \rightarrow 0 \}, \text{eff}(o) = \{ x \rightarrow 1 \} \)
- \( \text{pre}(o') = \{ a \rightarrow 0 \}, \text{eff}(o') = \{ y \rightarrow 1 \} \)
- \( \text{pre}(o_d) = \{ a \rightarrow 0 \}, \text{eff}(o_d) = \{ a \rightarrow 1, b_1 \rightarrow 1, \ldots, b_n \rightarrow 1 \} \)
- \( \text{pre}(o_t) = \{ a \rightarrow 1 \}, \text{eff}(o_t) = \{ a \rightarrow 0, b_1 \rightarrow 1, \ldots, b_n \rightarrow 1 \} \)
- \( \text{pre}(o_i) = \{ b_i \rightarrow 1 \}, \text{eff}(o_i) = \{ b_i \rightarrow 2 \} \) for \( 1 \leq i \leq n \)
- \( \text{pre}(o_{1i}) = \{ b_i \rightarrow 1 \}, \text{eff}(o_{1i}) = \{ b_i \rightarrow 1 \} \) for \( 1 \leq i \leq n \)
- \( I_n = \{ a \rightarrow 0, x \rightarrow 0, y \rightarrow 0, b_1 \rightarrow 0, \ldots, b_n \rightarrow 0 \} \)
- \( \gamma = \{ x \rightarrow 1, y \rightarrow 1 \} \)

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