Principles of AI Planning

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Exercise Sheet 6

Due: Friday, December 4th, 2015

Exercise 6.1 (Stability of h_{add}, 2 points)

Show that it is important to test for stability when computing h_{add} by giving an example where you get an unnecessarily high overestimation when not performing this test.

Hint: The solution to this exercise is a planning task and its relaxed planning graph where h_{add} is higher in the goal node in layer k than in the goal node of layer $j > k$.

Exercise 6.2 (Relaxed planning graph and heuristics, 4 points)

Consider the relaxed planning task Π^+ with variables $A = \{a, b, c, d, e\}$, operators $O = \{o_1, o_2, o_3\}$, $o_1 = \langle d, c \wedge (c \rhd e)\rangle$, $o_2 = \langle c, a\rangle$, $o_3 = \langle a, b\rangle$, goal $\gamma = b \wedge e$ and initial state $s = \{a \mapsto 0, b \mapsto 0, c \mapsto 0, d \mapsto 1, e \mapsto 0\}$. Solve the following exercises by drawing the relaxed planning graph for the lowest depth k that is necessary to extract a solution.

(a) Calculate $h_{\max}(s)$ for Π^+.

(b) Calculate $h_{\text{add}}(s)$ for Π^+.

(c) Calculate $h_{\text{sa}}(s)$ for Π^+.

(d) Calculate $h_{\text{FF}}(s)$ for Π^+.

Exercise 6.3 (Finite-domain representation, 1+1+2 points)

Consider the propositional Blocksworld planning task $\Pi = \langle A, I, O, \gamma\rangle$, with

- the set of variables

$$\begin{aligned} A = \{&\textit{A-clear}, \textit{B-clear}, \textit{C-clear}, \textit{A-on-B}, \textit{A-on-C}, \textit{A-on-T}, \\ &\textit{B-on-A}, \textit{B-on-C}, \textit{B-on-T}, \textit{C-on-A}, \textit{C-on-B}, \textit{C-on-T}\} \end{aligned}$$

- $I(a) = 1$ for $a \in \{\textit{B-on-T}, \textit{A-on-B}, \textit{A-clear}, \textit{C-on-T}, \textit{C-clear}\}$,
  $I(a) = 0$, else.
- O contains the actions

$$\begin{aligned} \text{move-}X\text{-}Y\text{-}Z &= \langle \textit{X-on-Y} \wedge \textit{X-clear} \wedge \textit{Z-clear}, \\ &\qquad \neg\textit{X-on-Y} \wedge \textit{Y-clear} \wedge \textit{X-on-Z} \wedge \neg\textit{Z-clear}\rangle \\ \text{move-}X\text{-Table-}Z &= \langle \textit{X-on-T} \wedge \textit{X-clear} \wedge \textit{Z-clear}, \\ &\qquad \neg\textit{X-on-T} \wedge \textit{X-on-Z} \wedge \neg\textit{Z-clear}\rangle \\ \text{move-}X\text{-}Y\text{-Table} &= \langle \textit{X-on-Y} \wedge \textit{X-clear}, \\ &\qquad \neg\textit{X-on-Y} \wedge \textit{Y-clear} \wedge \textit{X-on-T}\rangle \end{aligned}$$

  for pair-wise distinct $X, Y, Z \in \{A, B, C\}$
- $\gamma = \textit{B-on-C} \wedge \textit{C-on-A}$.

(a) The following mutex groups can be found for Π:

$$
\begin{aligned}
L_1 =& \{B\text{-}on\text{-}A,\ C\text{-}on\text{-}A,\ A\text{-}clear\}\\
L_2 =& \{A\text{-}on\text{-}B,\ C\text{-}on\text{-}B,\ B\text{-}clear\}\\
L_3 =& \{A\text{-}on\text{-}C,\ B\text{-}on\text{-}C,\ C\text{-}clear\}\\
L_4 =& \{A\text{-}on\text{-}B,\ A\text{-}on\text{-}C,\ A\text{-}on\text{-}T\}\\
L_5 =& \{B\text{-}on\text{-}A,\ B\text{-}on\text{-}C,\ B\text{-}on\text{-}T\}\\
L_6 =& \{C\text{-}on\text{-}A,\ C\text{-}on\text{-}B,\ C\text{-}on\text{-}T\}
\end{aligned}
$$

Specify a planning task Π' that is equivalent to Π and in finite-domain representation by using these mutex groups. Please name the variables in a reasonable way (e.g., analogously to the examples given in the lecture).

(b) Specify the propositional planning task Π'' that is induced by Π'.

(c) A planning task $\Pi' = \langle V, I', O', \gamma' \rangle$ in finite-domain representation is equivalent to a propositional planning task Π if there is an isomorphism between $\Pi'' = \langle A'', I'', O'', \gamma'' \rangle$ and Π, where Π'' is the propositional planning task induced by Π.

There is an isomorphism between Π'' and Π if there are injective mappings $f : S \mapsto S''$ and $g : O \mapsto O''$ (where S is the set of reachable states in Π and S'' the set of states in Π'') with:

- $I'' = f(I)$
- For reachable states s_1 and s_2, if $s_2 = app_o(s_1)$ then $f(s_2) = app_{g(o)}(f(s_1))$.
- For all reachable states $s \in S$ it is true that $s \models \gamma$ iff $f(s) \models \gamma''$.

Show that the planning task Π' from exercise (a) is equivalent to Π by specifiying $f : S \mapsto S''$ and $g : O \mapsto O''$ and showing that they have the required properties.

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