Principles of AI Planning

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Exercise Sheet 7

Due: December 14th, 2012

Exercise 7.1 (Finite-domain representation, 1.5+1.5+3 points)
Consider the propositional Blocksworld planning task $\Pi = \langle A, I, O, \gamma \rangle$, with

- the set of variables

$$A = \{A\text{-}clear, B\text{-}clear, C\text{-}clear, A\text{-}on\text{-}B, A\text{-}on\text{-}C, A\text{-}on\text{-}T, \\ B\text{-}on\text{-}A, B\text{-}on\text{-}C, B\text{-}on\text{-}T, C\text{-}on\text{-}A, C\text{-}on\text{-}B, C\text{-}on\text{-}T\}$$

- $I(a) = 1$ for $a \in \{B\text{-}on\text{-}T, A\text{-}on\text{-}B, A\text{-}clear, C\text{-}on\text{-}T, C\text{-}clear\}$,
  $I(a) = 0$, else.

- O contains the actions

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

  for pair-wise distinct $X, Y, Z \in \{A, B, C\}$

- $\gamma = B\text{-}on\text{-}C \wedge C\text{-}on\text{-}A$.

(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 (b) is equivalent to Π by specifiying $f : S \mapsto S''$ and $g : O \mapsto O''$ and showing that they have the required properties.

Exercise 7.2 (LM-cut heuristic, 4 Points)
Consider the STRIPS planning task specified by $\Pi = \langle A, I, O, \gamma \rangle$, where

$$
\begin{aligned}
A &= \{s, b, c, d, e, t\} \\
I &= \{s \mapsto 1, b \mapsto 0, c \mapsto 0, d \mapsto 0, e \mapsto 0, t \mapsto 0\} \\
O &= \{o_i \mid 1 \leq i \leq 6\} \\
o_1 &= \langle s, b \wedge c \rangle \\
o_2 &= \langle b, d \rangle \\
o_3 &= \langle c, e \rangle \\
o_4 &= \langle d \wedge e, t \rangle \\
o_5 &= \langle c \wedge e, t \rangle \\
o_6 &= \langle e, s \rangle \\
\gamma &= t
\end{aligned}
$$

Compute $h_{\text{LM-cut}}(I)$. In each iteration i of the algorithm (except for the last iteration where you identify $h^{c_i}_{\max}(t) = 0$), give the respective **pcf** D_i, the corresponding **justification graph** G_i of D_i, the **sets** V_i^*, V_i^0, V_i^b and L_i as well as the (intermediate) **heuristic value**.
Contrary to the lecture, please break pcf ties by choosing the **alphabetically largest** preposition (this ensures a unique solution).

Hints: When constructing an s-t-cut, please keep the definition in mind (simply drawing a line through the graph may yield wrong results). Furthermore, a justification graph can contain multiple edges as well as cycles, although the example in the lecture did not.

Note: The exercise sheets may and should be worked on in groups of two students. Please state both names on your solution (this also holds for submissions by e-mail).