Planning and Optimization

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Exercise Sheet 13

Due: January 4, 2017

Exercise 13.1 (1+1+3+1 bonus marks)

Consider the delete-relaxed STRIPS planning task $\Pi = \langle V, I, O, G \rangle$ that models a robot with one gripper that has to carry two balls b_1 and b_2 from one (left) room to another (right) room. Formally, Π is defined as follows:

- $V = \{$`b1-left`, `b2-left`, `b1-right`, `b2-right`, `b1-robot`, `b2-robot`, `robot-right`, `robot-left`$\}$
- $I = \{$`b1-left`, `b2-left`, `robot-left`$\}$
- $O = \{o_1, o_2, o_3, o_4, o_5\}$
- $G = \{$`b1-right`, `b2-right`$\}$

The operators are defined as follows:

- $pre(o_1) = \{$`b1-left`, `robot-left`$\}$, $add(o_1) = \{$`b1-robot`$\}$, $del(o_1) = \emptyset$, $cost(o_1) = 1$
- $pre(o_2) = \{$`b2-left`, `robot-left`$\}$, $add(o_2) = \{$`b2-robot`$\}$, $del(o_2) = \emptyset$, $cost(o_2) = 1$
- $pre(o_3) = \{$`robot-left`$\}$, $add(o_3) = \{$`robot-right`$\}$, $del(o_3) = \emptyset$, $cost(o_3) = 2$
- $pre(o_4) = \{$`b1-robot`, `robot-right`$\}$, $add(o_4) = \{$`b1-right`$\}$, $del(o_4) = \emptyset$, $cost(o_4) = 1$
- $pre(o_5) = \{$`b2-robot`, `robot-right`$\}$, $add(o_5) = \{$`b2-right`$\}$, $del(o_5) = \emptyset$, $cost(o_5) = 1$

We consider admissible delete-relaxed and landmark heuristics for this task.

(a) Compute $h^*(I)$ and $h^+(I)$ (without proof). Compare and disucss the relation of these values for the given task.

(b) Compute $h^{\max}(I)$. Justify your answer with the relaxed task graph.

(c) Compute $h^{\text{LM-cut}}(I)$. For this computation, first introduce corresponding zero cost operators to obtain exactly one initial atom $\{i\}$ and exactly one goal atom $\{g\}$. In each iteration of the algorithm, provide one of the possible justication graphs, the cut, the value by how much $h^{\text{LM-cut}}(I)$ is increased, and the altered operator costs.

(d) Compare and discuss the heuristic values from (a), (b), and (c).

Please turn around

Exercise 13.2 (1+0.5+1.5+1+1+1 bonus marks)

Consider the following SAS$^+$ planning task $\Pi = \langle V, I, O, \gamma \rangle$:

$$
\begin{aligned}
V &= \{x, y\} \text{ with } \mathrm{dom}(x) = \{A, B\} \text{ and } \mathrm{dom}(y) = \{0, 1, 2, 3\} \\
I &= \{x \mapsto A, y \mapsto 0\} \\
O &= \{o_1, o_2, o_3, o_4, o_5\}, \text{ where} \\
&\quad o_1 = \langle x = A, x := B, 1\} \\
&\quad o_2 = \langle x = B \wedge y = 0, x := A \wedge y := 1, 1\rangle \\
&\quad o_3 = \langle x = B \wedge y = 1, y := 2, 1\rangle \\
&\quad o_4 = \langle x = B \wedge y = 2, x := A, 1\rangle \\
&\quad o_5 = \langle x = A \wedge y = 2; y := 3, 1\rangle \\
\gamma &= (x := B \wedge y := 3)
\end{aligned}
$$

(a) Provide $\mathcal{T}^{\pi_{\{x\}}}$ and by $\mathcal{T}^{\pi_{\{y\}}}$ graphically and determine the heuristic values $h^{\{x\}}(I)$ and $h^{\{y\}}(I)$.

(b) Compute the canonical heuristic $h^{\mathcal{C}}(I)$.
(*Hint: For two PDBs, the canonical heuristic must be either the sum or the maximum of the two individual estimates.*)

(c) Provide $\mathcal{T}^{\pi_{\{x\}}} \otimes \mathcal{T}^{\pi_{\{y\}}}$ graphically and determine the heuristic value $h^{\pi_{\{x\}} \otimes \pi_{\{y\}}}(I)$.

(d) Compute the optimal non-negative cost partitioning for $\pi_{\{x\}}$ and $\pi_{\{y\}}$ (without proof) and let $\langle \Pi_x, \Pi_y \rangle$ be the induced planning tasks. Determine $h^{\mathrm{CP+}}(I) := h^{\{x\}}_{\Pi_x}(I) + h^{\{y\}}_{\Pi_y}(I)$.

(e) Compute the optimal general cost partitioning for $\pi_{\{x\}}$ and $\pi_{\{y\}}$ (without proof) and let $\langle \Pi'_x, \Pi'_y \rangle$ be the induced planning tasks. Determine $h^{\mathrm{CP}}(I) := h^{\{x\}}_{\Pi'_x}(I) + h^{\{y\}}_{\Pi'_y}(I)$.

(f) Compare and discuss the heuristic values from (b), (c), (d), and (e).

The exercise sheets can be submitted in groups of two students. Please provide both student names on the submission.