## Planning and Optimization

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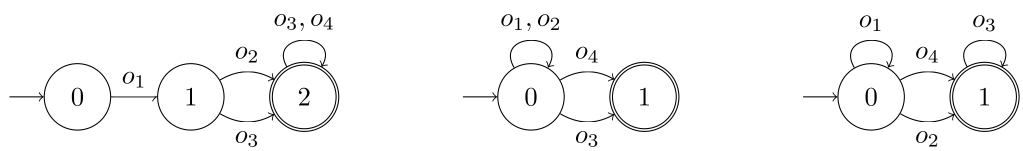
# Exercise Sheet 11

**Due: December 14, 2016**

**Exercise 11.1** (1+2+2 marks)

Consider the planning task $\Pi = \langle V, I, O, \gamma \rangle$ with $V = \{a, b, c\}$, $I = \{a \mapsto 0, b \mapsto 0, c \mapsto 0\}$, $O = \{o_1, o_2, o_3, o_4\}$ and $\gamma = (a = 2 \land b = 1 \land c = 1)$. The cost of each operator is 1. The atomic abstractions to each variable are given below (atomic abstraction to $a$ on the left, to $b$ in the middle, and to $c$ on the right).




(a) For abstractions $\alpha_1, \ldots, \alpha_n$, the uniform cost partitioning is defined for all $o \in O$ and $1 \leq i \leq n$ by

$$cost_i(o) := \begin{cases} \frac{cost(o)}{n_o} & \text{if } \alpha_i \text{ contains a transition } s \xrightarrow{o} t \text{ with } s \neq t \\ 0 & \text{otherwise,} \end{cases}$$

where $n_o$ is the number of abstractions which contain a transition $s \xrightarrow{o} t$ with $s \neq t$. Compute the uniform cost partitioning and the corresponding heuristic value in the initial state $I$.

(b) For abstractions $\alpha_1, \ldots, \alpha_n$, the zero-one cost partitioning is defined for all $o \in O$ by $cost_i(o) := cost(o)$ for exactly one $i \in \{1, \ldots, n\}$, and $cost_j(o) := 0$ for $j \neq i$. Compute a zero-one cost partitioning which yields the maximal heuristic value in the initial state $I$ among all zero-one cost partitionings. Provide the corresponding heuristic value in $I$.

(c) Provide a cost partitioning that yields a higher heuristic value than the cost partitionings from (a) and (b). What is the value of the corresponding heuristic in the initial state?

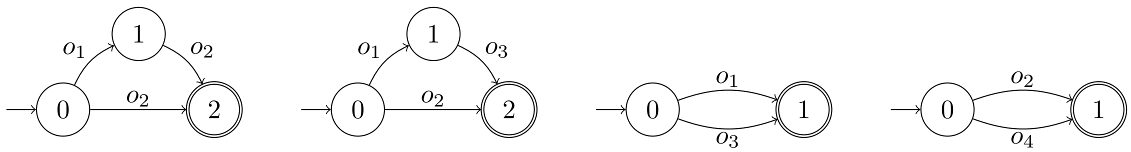
**Exercise 11.2** (2 marks)

In the lecture, we have seen how to compute a uniform cost partitioning for a set of disjunctive action landmarks (chapter D2, slide 7 in the handout version). Analogously, the set of disjunctive action landmarks which is built during the computation of the LM-cut heuristic induces a (non-uniform) cost partitioning. For a sequence $\langle L_1, \ldots, L_n \rangle$ of disjunctive landmarks that is computed by LM-cut, formalize the induced cost partitioning $\langle cost_{L_1}, \ldots, cost_{L_n} \rangle$ by LM-cut.

*Please turn around*

**Exercise 11.3** (3+1+1 marks)

Consider a planning task with four variables and with operator set $O = \{o_1, o_2, o_3, o_4\}$. The cost function is defined as $cost(o_i) = i$ for $i \in \{1, \dots, 4\}$. Consider the four pattern databases induced by the four projections to the variables, which are given as follows (for brevity, self loops are omitted):




(a) Provide the set of operator-counting constraints $C$ from the post-hoc optimization heuristic for these four PDBs. Use the online LP solver available at `http://www.phpsimplex.com/` to compute $h^{LP}_{C}(s_I)$. Attach a screenshot of the output of the LP solver to your solution.

(b) Now consider the set of operator-counting constraints $C'$, which contains the operator-counting constraint from the disjunctive action landmark $L = \{o_3, o_4\}$ in addition to the operator-counting constraints from $C$. Provide $C'$, use the online LP solver available at `http://www.phpsimplex.com/` to compute $h^{LP}_{C'}(s_I)$ and attach a screenshot of the output of the LP solver to your solution.

(c) Compare $h^{LP}_{C'}(s_I)$, $h^{\mathrm{MHS}}(\{L\})$, and $h^{LP}_{C}(s_I)$ and discuss the differences.

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