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Exercise Sheet 4.

Solutions due Wednesday, **January 9**, 23:59, in Moodle. [1]

Exercise 13. (7 Points)

Consider a slightly modified version of the planning task with Rudolph the reeindeer, the sleigh and the 2 big Amazon gifts.

So, poor Rudolph has to transport two gifts to their goal location with his sleigh for Santa (this year he split his work to all his reeinders). At any point in time only one gift can be taken by Rudolph (There are 2 very nice big Amazon Xmas gifts and a small poor reindeer). Formally, this task is encoded as the following FDR planning task $\Pi = (V, A, I, G)$ where

- $V = \{r, g_1, g_2, c\}$ with domains
  - $D(r) = \{1, 2, 3\}$,
  - $D(g_1) = D(g_2) = \{1, 2, 3, R\}$,
  - $D(c) = \{0, 1\}$ (c is the capacity of the reeindeer)
- $A = \{drive(x, y), put_{on}(i, z), put_{down}(i, z)\}$ for $\{x, y\} \in \{\{1, 2\}, \{2, 3\}\}$, $i \in \{1, 2\}$, and $z \in \{1, 2, 3\}$
  - $pre(drive(x, y)) = \{r = x\}$,
    $eff(drive(x, y)) = \{r = y\}$
  - $pre(put_{on}(i, z)) = \{r = z, g_i = z, c = 1\}$,
    $eff(put_{on}(i, z)) = \{g_i = R, c = 0\}$
  - $pre(put_{down}(i, z)) = \{r = z, g_i = R, c = 0\}$,
    $eff(put_{down}(i, z)) = \{g_i = z, c = 1\}$
- $I = \{r = 1, g_1 = 2, g_2 = 3, c = 1\}$,
- $G = \{r = 1, g_1 = 3, g_2 = 2\}$.

[1] At most 3 authors per solution. Include the names and matriculation numbers of all authors in the solution. Submission of solutions is via the course Moodle pages.
Please note that you are *not* allowed to copy from other groups!

All actions have unit-cost.

(i) Draw the atomic projections of π.

(ii) Compute a Merge-and-Shrink abstraction by first merging the variables r and g1, and merging g2 with the result. After each merge, perform a shrink operation on the newly generated abstract transition system that leaves no more than 4 states, in a way such that the goal distance for the initial state in the final abstract state space is as high as possible. After each merge and each shrink step, draw the resulting abstract transition system. (Note that we stop after merging g2 — without doing a second shrink operation and without merging variable c.) What is the resulting heuristic value for the initial state?

Exercise 14. (6 Points)

Consider again the FDR task Π from Exercise 13. For this exercise, assume that the reindeer r has first to deliver gift 1 g_1 and then gift2, g_2 (actions put_{down} for g_2 have as precondition that g_1 has been delivered).

(i) Compute the set of necessary subgoals of this task.

(ii) For every fact p of Π argue why it is, or is not, a delete relaxation landmark for I.

(iii) For each delete relaxation landmark p from (ii), give the induced disjunctive action landmark $L(p)$. Draw the compatibility graph for $\mathcal{C} = \{L(p) \mid p \text{ is a delete relaxation landmark}\}$, and give the corresponding set of maximal cliques $cliques(\mathcal{C})$. What is $h^{\mathcal{C}}(I)$?

Exercise 15. (7 Points)

Consider the TSP in Australia task encoded as the following FDR planning task $\Pi = (V, A, I, G)$ where

- $V = \{at, v_{Ad}, v_{Br}, v_{Pe}, v_{Da}\}$ with domains
  - $D(at) = \{Sy, Ad, Br, Pe, Da\}$,
  - $D(vX) = \{F, T\}$,
- $A = \{drive(x, y)\}$ for $\{x, y\} \in \{\{Pe, Ad\}, \{Da, Ad\}, \{Ad, Sy\}, \{Sy, Br\}\}$
  - $pre(drive(x, y)) = \{at = x\}$,
    $eff(drive(x, y)) = \{at = y, v_y = T\}$
- $I = \{at = Sy, v_{Ad} = F, v_{Br} = F, v_{Pe} = F, v_{Da} = F\}$,
- $G = \{at = Sy, v_{Ad} = T, v_{Br} = T, v_{Pe} = T, v_{Da} = T\}$,

All actions have unit-cost.

(i) Describe the LP of the operator-counting heuristic for the initial state that uses all flow constraints. Indicate the variables, constraints, and objective function. What is the heuristic value returned for the initial state?

(ii) Can the heuristic above be enhance by any delete-relaxed disjunctive action landmark constraint? If so, indicate what is the landmark, the corresponding constraint, and what will be the new heuristic value.