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Exercise Sheet 5.

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

Exercise 16. (7 Points)

For this problem consider you want to go to Uni, and you have 2 ways of doing it - either by bus, or by motorcycle. Going by motorcycle requires some extra actions in order for you to be safe, such as taking a jacket and a cap and then taking the motorcycle from the basement and drive to Uni, or drive via bus.

The STRIPS planning task $\Pi = \{P, A, c, I, G\}$ as it is illustrated in Figure 1, with $P = \{you, Jacket, Cap, Motorbike, Uni\}$, $I = \{i\}$, $G = \{g\}$ and the following actions:

- $takeJacket = (\{you\}, \{Jacket\}, \emptyset)$ and cost $c(takeJacket) = 1$.
- $takeCap = (\{you\}, \{cap\}, \emptyset)$ and cost $c(takeCap) = 2$.
- $takeMotorbike = (\{Jacket, cap\}, \{Motorbike\}, \emptyset)$ and cost $c(takeMotorbike) = 2$.
- $driveUni = (\{Motorbike\}, \{Uni\}, \emptyset)$ and cost $c(driveUni) = 1$.
- $takeBus = (\{you\}, \{Uni\}, \emptyset)$ and cost $c(takeBus) = 5$.

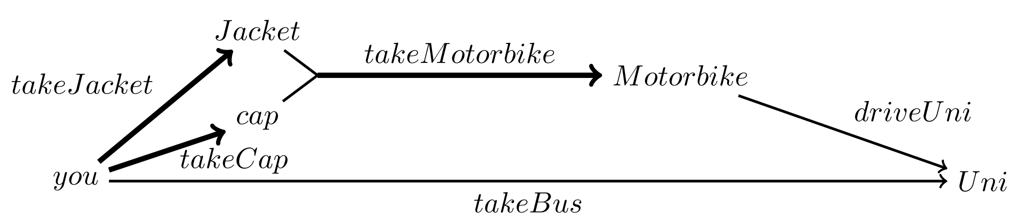

Figure 1: Illustration of the STRIPS task Π.

Calculate the heuristic value for the initial state using the LM-cut heuristic. To do so, execute the algorithm that is given in the lecture slides. To be more specific, for each

[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!

iteration of the algorithm draw the graph G as it is specified there. Annotate each fact p with the corresponding $h^1(I, \{p\})$ value and each action with its updated cost. Additionally, cross out the action(s) that are part of the current "cut" and provide the cost partitioning where it is different from 0.

Exercise 17. (8 Points)

Consider the following FDR planning task $\Pi = \langle V, A, I, G \rangle$ where

- $V = \{R_1, R_2, L_1, L_2\}$ with domains $D_{R_1} = D_{R_2} = \{1, 2, 3\}$ and $D_{L_1} = D_{L_2} = \{0, 1\}$.
- $A = \{\mathit{move}(R_i, x, y), \mathit{enter}(R_i), \mathit{unlock}(L_i)\}$ for $i \in \{1, 2\}$ and $\{x, y\} = \{1, 2\}$ where
  - $\mathit{move}(R_i, x, y)$: $\mathit{pre} = \{R_i = x\}$, $\mathit{eff} = \{R_i = y\}$,
  - $\mathit{enter}(R_i)$: $\mathit{pre} = \{R_i = 2, L_i = 1\}$, $\mathit{eff} = \{R_i = 3\}$,
  - $\mathit{unlock}(L_1)$: $\mathit{pre} = \{L_1 = 0, R_2 = 2\}$, $\mathit{eff} = \{L_1 = 1\}$,
  - $\mathit{unlock}(L_2)$: $\mathit{pre} = \{L_2 = 0, R_1 = 2\}$, $\mathit{eff} = \{L_2 = 1\}$.
- $I = \{R_1 = 1, R_2 = 1, L_1 = 0, L_2 = 0\}$,
- $G = \{R_1 = 3, R_2 = 3\}$.

(i) Which actions interfere with each other? Which actions do not interfere, but are not commutative? For actions that interfere, give a state where they interfere. For actions that neither interfere nor are commutative, give a brief explanation why this is the case.

(ii) Compute two strong stubborn set for the initial state I. To do so, use the algorithm on the slides (Chapter 18, slide 28). Give the initialization of $S3$, i.e., $A_{I \to^* G}$, and for each iteration give the action a selected from $S3$ and the actions added to $S3$. To compute a necessary enabling set, use the approximation shown on slide 31 of Chapter 18.

Exercise 18. (7 Points)

Consider the following FDR planning task $\Pi = \langle V, A, I, G \rangle$ where we have two rockets that can hold up to 2 units of fuel each. Our goal is to launch both rockets in order (variable L records how many rockets have been launched so far). To launch a rocket, its fuel tank must not be empty (i.e., it may have one or two units of fuel) and, after launching it the fuel tank becomes empty, independently of how much fuel it had before. At the end, the first rocket must have the fuel tank full.

- $V = \{R_1, R_2, L\}$ with domains $D_{R_1} = D_{R_2} = \{F0, F1, F2\}$ and $D_L = \{L0, L1, L2\}$.
- $A = \{\mathit{refuel}(R_i, x, y)$, for $i \in \{1, 2\}$ and $(x, y) \in \{(F0, F1), (F1, F2)\} \cup \{\mathit{launchFirst}(x), \mathit{launchSecond}(x)$ for $x \in \{F1, F2\}\}$
  - $\mathit{refuel}(R_i, x, y)$: $\mathit{pre} = \{R_i = x\}$, $\mathit{eff} = \{R_i = y\}$,
  - $\mathit{launchFirst}(x)$: $\mathit{pre} = \{R_1 = x, L = L0\}$, $\mathit{eff} = \{R_1 = F0, L = L1\}$,
  - $\mathit{launchSecond}(x)$: $\mathit{pre} = \{R_2 = x, L = L1\}$, $\mathit{eff} = \{R_2 = F0, L = L2\}$,
- $I = \{R_1 = F0, R_2 = F0, L = L0\}$,
- $G = \{L = L2, R_1 = F2\}$.

(i) Draw the atomic transition systems of the planning task.

(ii) Speficy the coarsest goal-respecting relation on the three atomic transition systems. To do so, for each of them write a table with a row and one column for each abstract state like the following. Mark cell in row X and column Y iff $X \preceq Y$.

$\preceq^{R_1}$	F0	F1	F2
F0			
F1			
F2			

$\preceq^{R_2}$	F0	F1	F2
F0			
F1			
F2			

$\preceq^{L}$	L0	L1	L2
L0			
L1			
L2			

(iii) What labels are equivalent in all but one transition system? Remember that you may consider these labels as if they were the same label during the NOOP-dominance computation.

(iv) What labels are dominated by NOOP in all transition systems but one given the coarsest goal-respecting relations of part (i)?

(v) Compute the coarsetst NOOP-dominance relation on these three transition systems. Starting from the coarsest-goal respecting relations of part (*ii*), you must remove cells from the relation one by one, until all of them follow the definition of NOOP-dominance given the current relation. For each cell removed that way, specify what cell is removed, and what transition causes it to not follow the definition. For example, $X \not\preceq Y$ because $X \xrightarrow{l} Z$, $Y \not\preceq Z$ and Y does not have any transition to anything that dominates Z. Indicate if removing a pair from the relation causes NOOP to no longer dominate another label in all but one transition system. Draw the final NOOP-dominance relation obtained this way in tables as the ones in part (ii).

(vi) Consider the following pairs of states. Which of the dominance relations hold according to the relation that you computed in part (*iv*)? For those that do not hold, indicate why.

- $(L = L0, R_1 = F2, R_2 = F2) \preceq (L = L0, R_1 = F2, R_2 = F1)$
- $(L = L0, R_1 = F2, R_2 = F2) \preceq (L = L0, R_1 = F1, R_2 = F2)$
- $(L = L1, R_1 = F2, R_2 = F2) \preceq (L = L0, R_1 = F2, R_2 = F2)$
- $(L = L1, R_1 = F2, R_2 = F2) \preceq (L = L2, R_1 = F2, R_2 = F2)$
- $(L = L1, R_1 = F0, R_2 = F2) \preceq (L = L2, R_1 = F1, R_2 = F1)$