SAARLAND UNIVERSITY

Dr. Álvaro Torralba

Dr. Cosmina Croitoru, Daniel Gnad, Marcel Steinmetz

Exercise Sheet 3.

Solutions due Wednesday, **December 12**, 23:59, in Moodle. [1]

Exercise 9. (7 Points)

Consider a slightly modified version of the planning task with the pigeons from the previous exercise sheet.

Let $\Pi = \{V, A, I, G\}$ be an FDR planning task describing the job of a modern pigeon, that has to go to the place where the message is, take it and transmit a message hidden in a place, then send it over via SMS to the receiver. Note that, due to low mobile signal, the pigeon has to go to the next location to send the message (this is next to a tree - the only place where the mobile phone is working). Formally, the task is defined as follows:

- $V = \{\textit{at-pigeon}, \textit{mes-found}, \textit{mes-sent}\}$, with
  - $D(\textit{at-pigeon}) = \{L_1, L_2, L_3\}$,
  - $D(\textit{mes-found}) = D(\textit{mes-sent}) = \{\textit{true}, \textit{false}\}$.
- $A = \{\textit{move}(x, y), \textit{take-mes}, \textit{send-mes}\}$, with
  - $\textit{pre}(\textit{move}(x, y)) = \{\textit{at-pigeon} = x\}$, with $\{x, y\} \in \{\{L_1, L_2\}, \{L_2, L_3\}\}$
    $\textit{eff}(\textit{move}(x, y)) = \{\textit{at-pigeon} = y\}$.
  - $\textit{pre}(\textit{take-mes}) = \{\textit{at-pigeon} = L_2\}$,
    $\textit{eff}(\textit{take-mes}) = \{\textit{mes-found} = \textit{true}\}$,
  - $\textit{pre}(\textit{send-mes}) = \{\textit{at-pigeon} = L_3, \textit{mes-found} = \textit{true}\}$,
    $\textit{eff}(\textit{send-mes}) = \{\textit{mes-sent} = \textit{true}\}$.
- $I = \{\textit{at-pigeon} = L_1, \textit{mes-found} = \textit{false}, \textit{mes-sent} = \textit{false}\}$.
- $G = \{\textit{mes-sent} = \textit{true}\}$.

All actions have unit-cost.

[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!

(i) Give the h^{add} best-supporter function for the initial state. More precisely, for each variable assignment p that is not true initially, give the value $bs_I^{add}(p)$.

(ii) Do relaxed plan extraction for the initial state I using the best-supporter function computed in (i). Show how *Open* is initialized and for each iteration of the while loop, indicate which fact g is removed from *Open*, which action is added to *RPlan*, and which facts are added to *Open*. Give the final content of *RPlan*. What is the $h^{\mathrm{FF}}(I)$ value?

(iii) Can the actions of *RPlan* from (ii) be ordered to an optimal delete-relaxed plan for the initial state? Briefly justify your answer.

Exercise 10. (7 Points)

Consider the following transportation problem where poor Rudolph has to transport two gifts to their goal location with his slide 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 $z \in \{1, 2, 3\}$
  - $pre(drive(x, y)) = \{r = x\}$,
    $e\!f\!f(drive(x, y)) = \{r = y\}$
  - $pre(put_{on}(i, z)) = \{r = z, g_i = z, c = 1\}$,
    $e\!f\!f(put_{on}(i, z)) = \{g_i = R, c = 0\}$
  - $pre(put_{down}(i, z)) = \{r = z, g_i = R, c = 0\}$,
    $e\!f\!f(put_{down}(i, z)) = \{g_i = z, c = 1\}$
- $I = \{r = 1, g_1 = 2, g_2 = 3, c = 1\}$,
- $G = \{r = 1, g_1 = 3, g_2 = 2\}$.

All actions have unit-cost.

Consider the patterns $P_1 = \{r\}$, $P_2 = \{g_1, c\}$, and $P_3 = \{r, g_2\}$, $P_4 = \{g_1, c, r\}$.

(i) Compute a pattern database for each of the three patterns. To do so, execute the algorithm given in the lecture: Construct the reachable state space $\Theta_\Pi^{\pi_{P_i}}$ of the syntactic projection onto P_i by a breadth-first forward search. Write up the states, annotating them by their variable values (e.g., the initial state of $\Theta_\Pi^{\pi_{P_3}}$ can be notated $r1g_23$), and draw an edge from each state to each of its successor states. Annotate each of the states in $\Theta_\Pi^{\pi_{P_i}}$ with its goal distance.

(ii) Create the perfect hash function and corresponding look-up table for the pattern database for P_3. Do so using the method given in the lecture, setting $v_1 = r$ and $v_2 = g_2$ with the correspondences $D_r = \{1, 2, 3\} \approx \{0, 1, 2\}$ and $D_{g_2} = \{1, 2, 3, R\} \approx \{0, 1, 2, 3\}$. Give the result in terms of the final table containing, as in the lecture slides, one row with the states, one row with their hash values, and one row with the corresponding heuristic values.

(iii) Build the compatibility graph for $\mathcal{C} = \{P_1, P_2, P_3, P_4\}$. What is the value of $h^{\mathcal{C}}(I)$? What is the value of $h^{\mathcal{C}_1}(I)$ where $\mathcal{C}_1 = \{P_1, P_2\}$? How about the value of $h^{\mathcal{C}_2}(I)$ where $\mathcal{C}_2 = \{P_1, P_2, P_4\}$? Please explain how you got the values for $\mathcal{C}$ and $\mathcal{C}_1$.

Exercise 11. (3 + 3 = 6 Points)

Consider again the FDR task Π from Exercise 10. For this exercise, assume that the reindeer variable r is painted black and all other variables $V \setminus \{r\}$ are red. For each of the following relaxed plans, execute the relaxed plan repair and the relaxed facts following algorithm to compute a red-black plan for the modified initial state $I = \{r = 2, g_1 = 1, g_2 = 3, c = 1\}$ and goal $G = \{r = 1, g_1 = 3, g_2 = 1\}$.

(i) $\pi_1^{RB} = \langle drive(2,1), drive(2,3), put_{on}(1,1), put_{on}(2,3), put_{down}(2,1), put_{down}(1,3)\rangle$,

(ii) $\pi_2^{RB} = \langle drive(2,1), put_{on}(1,1), drive(2,3), put_{down}(1,3), put_{on}(2,3), put_{down}(2,1)\rangle$.

For each step of the relaxed plan repair algorithm, give the black precondition(s) that have to be achieved, and the sequence of actions returned by the "Achieve" function.

For each iteration of the relaxed facts following algorithm, provide the set of already achieved red facts R and the set of black values B, as defined in the lecture. Indicate which action you choose, and give its not reached black precondition(s) as well as the sequence of actions returned by "Achieve". It is sufficient to only list the facts that are newly inserted into R and B.

Exercise 12. (3 Extra Points)

Prove that h^{FF} based on the $h^{\max}$ supporter function is not admissible even if we restrict to uniform costs. Your proof should not rely on "bad tie-breaking", i.e., whenever there are multiple "equally good" best supporters for a fact, your proof should work independent of which best supporter is chosen.