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Exercise Sheet 2.

Solutions due Wednesday, **November 21**, 23:59, in Moodle. [1]

Exercise 5. (7 Points)

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 trasmit 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 - only place that the handy is working). Formally, the task is defined as follows:

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

(i) Compute the value of the additive heuristic for the initial state, $h^{add}(I)$, by using the dynamic programming algorithm from the lecture. Write up the table of intermediate values for each iteration of the algorithm, until convergence.

[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!

(ii) What is the value of $h^{max}(I)$ (you don't need to provide the full table)? And what is the value of $h^{ff}(I)$?

Exercise 6. (7 Points)

On the planning task from Exercise 5, run Greedy Best-First Search with the h^+ heuristic. Draw the search graph annotating each state with its heuristic value and the order of expansion. If there are multiple states that could be expanded in a step of the search, choose the one where the rover is in the lowest positions, where $L_1 < L_2 < L_3$. Mark and prune duplicate states.

Exercise 7. (6 Points)

Consider the following modification of the planning task specified in exercise 5, where the pigeon doesn't have to send the message anymore, but has to return to its initial position. Note also that the pigeon can now fly directly from L_3 to L_1.

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

1. Compute the value of the critical path heuristic (with $m = 2$) for the initial state, $h^2(I)$. Write down the table of intermediate values for each iteration of the algorithm, until convergence. You can use abbreviations for the variable names.
2. What is the value of $h^1(I)$ (you don't need to provide the full table)? Does it differ from $h^2(I)$? If yes, why? If not, why not? (So, please explain!)

Exercise 8. (3 Extra Points)

As defined in the lecture, the perfect regression heuristic r^* for a STRIPS task Π is the function $r^*(s) := r^*(s, G)$ where $r^*(s, g)$ is the point-wise greatest function that satisfies $r^*(s, g) =$

$$\begin{cases} 0 & g \subseteq s \\ min_{a \in A, regr(g,a) \text{ is defined}} \; c(a) + r^*(s, regr(g, a)) & \text{otherwise} \end{cases}$$

Prove that, for $r^* = h^*$ to hold true, it is necessary for $r^*(s, g)$ to be the *point-wise greatest function* satisfying this equation, i.e., among all functions r satisfying the equation, the one that is maximal for every pair s, g. To do so, construct a counter-example task, where there exists a non-point-wise-maximal such function r, that is not identical with h^*.

Tip: You should think about how to construct cases s, g for which there exist functions r_1, r_2 satisfying the equation with $r_1(s, g) \neq r_2(s, g)$. This can be done by constructing cycles of 0-cost actions achieving unreachable facts.