Foundations of Artificial Intelligence

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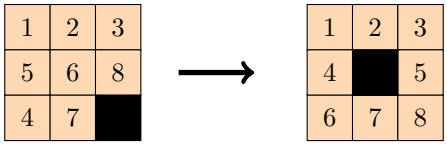
Exercise Sheet 11

Due: May 13, 2020

Important: For submission, consult the rules at the end of the exercise. Non-adherence to the rules will lead to your submission not being corrected.

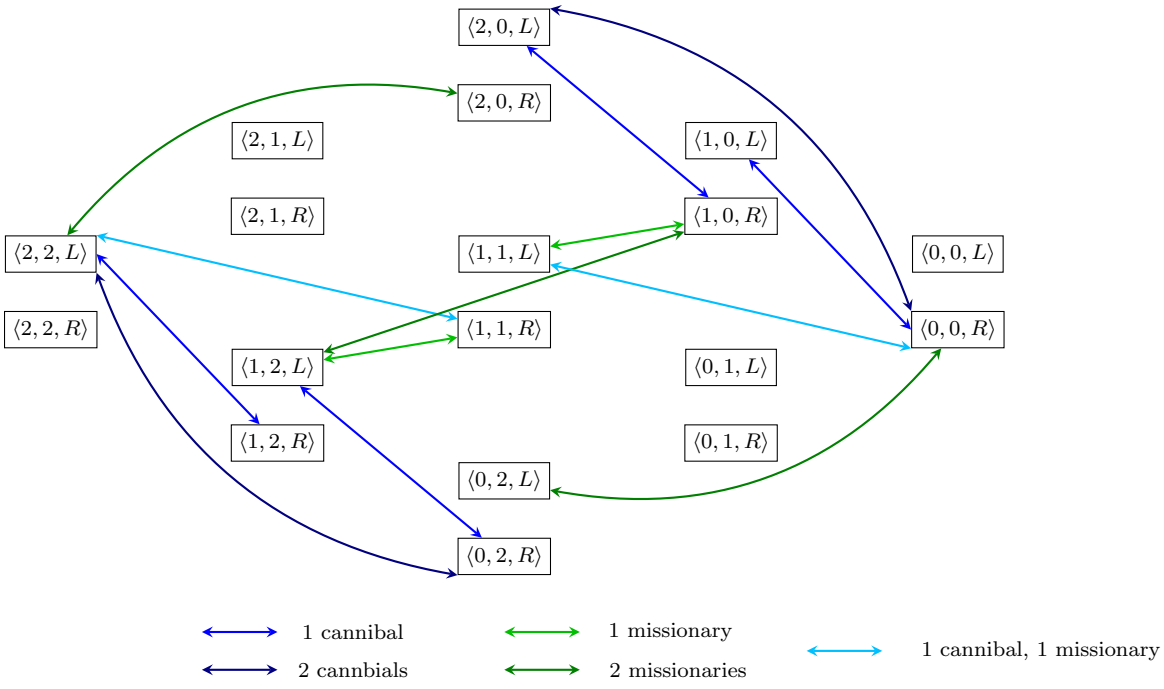
Exercise 11.1 (2 marks)

Formalize the following 8-puzzle instance in SAS$^+$:



Exercise 11.2 (1.5+1+0.5+1 marks)

The following graph depicts the search space of a cannibals and missionary problem with two cannibals and two missionaries:



A state is represented as a tuple $\langle C, M, B\rangle$, where C and M (with $\mathrm{dom}(C) = \mathrm{dom}(M) = \{0, 1, 2\}$) denote how many cannibals and missionaries respectively are on the left shore, and B (with $\mathrm{dom}(B) = \{L, R\}$) denotes on which shore the boat is. The cost of all operators is 1.

(a) Draw the abstract state space that is induced by the projection $P = \{C, M\}$ in the same way as the above depiction of the concrete state space.

(b) Use the abstraction from part (a) to derive a pattern database heuristic. Provide all database entries, i.e., the abstract distances for all states in the abstract state space.

(c) What is $h^{\{C,M\}}(I)$?

(d) For a cannibals and missionaries problem with n cannibals and missionaries, what would $h^{\{C,M\}}(I)$ be? Justify your answer.

Exercise 11.3 (1.5+1.5 marks)

Consider a task with 5 actions, cost function $cost = \{a_1 \mapsto 3, a_2 \mapsto 2, a_3 \mapsto 0, a_4 \mapsto 5, a_5 \mapsto 1\}$ and landmarks $\mathcal{L} = \{\{a_1, a_2\}, \{a_4\}, \{a_1, a_3, a_4\}, \{a_2, a_5\}\}$.

(a) Provide the LP encoding $h^{\mathrm{OCP}}(I)$ (you do not need to solve it).

(b) Given a task with action set A, cost function *cost* and landmark set $\mathcal{L}$, could adding an additional landmark l decrease $h^{\mathrm{MHS}}(I)$? Justify your answer.

Hint: Consider how the minimum hitting sets for $H = \langle X, \mathcal{F}, c\rangle$ and $H' = \langle X, \mathcal{F} \cup \{S\}, c\rangle$ (i.e., same support set and cost function, but H' must hit an additional set) are related.

Exercise 11.4 (3 marks)

Consider the delete-free STRIPS planning task $\Pi^+ = \langle V, I, G, A\rangle$, with variables $V = \{a, b, c, d, e\}$, initial state $I = \{i\}$, goal description $G = \{g\}$, and actions $A = \{a_1, \ldots, a_6\}$, where

$$
\begin{array}{lll}
pre(a_1) = \{i\} & add(a_1) = \{a, b\} & cost(a_1) = 2 \\
pre(a_2) = \{i\} & add(a_2) = \{c\} & cost(a_2) = 1 \\
pre(a_3) = \{a, b\} & add(a_3) = \{c, d\} & cost(a_3) = 3 \\
pre(a_4) = \{c\} & add(a_4) = \{b, e\} & cost(a_4) = 2 \\
pre(a_5) = \{c, e\} & add(a_5) = \{d\} & cost(a_5) = 4 \\
pre(a_6) = \{d, e\} & add(a_6) = \{g\} & cost(a_6) = 0.
\end{array}
$$

Compute $h^{\text{LM-cut}}(I)$ and provide all intermediate results in the same way they were given in the example of the lecture. Specifically, provide for each iteration (except the last):

- the justification graph with $h^{\max}$ annotations and marked goal zone
- the cut
- the cost of the cut
- the updated action costs

In cases where the precondition choice function is not deterministic, choose the precondition in alphabetical order.

Submission rules:

- Upload a single PDF file (ending .pdf). If you want to submit handwritten parts, include their scans in the single PDF. Put the names of all group members on top of the first page. Use page numbers or put your names on each page. Make sure your PDF has size A4 (fits the page size if printed on A4).
- Only upload one submission per group. Do not upload several versions, i.e., if you need to resubmit, use the same file name again so that the previous submission is overwritten.