Foundations of Artificial Intelligence

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Exercise Sheet 4

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Exercise 4.1 (2+1 marks)

Consider the "missionaries and cannibals" problem from the lecture. As a quick reminder: states in this problem are triples $\langle m, c, b \rangle \in \{0, 1, 2, 3\} \times \{0, 1, 2, 3\} \times \{0, 1\}$, where m gives the number of missionaries, c the number of cannibals and b the number of boats that are at the *wrong* river bank in the given state. Keep in mind that the boat can carry no more than two persons.
Let the initial state be $\langle 3, 3, 1 \rangle$ and the goal state be $\langle 0, 0, 0 \rangle$.

(a) Apply depth-limited tree search with a depth limit of 3 to the initial state (i.e., simulate a call to `depth_limited_search(init(), 3)`). Provide the resulting search tree, including the order in which search nodes are expanded. Successor nodes are generated by applying the following actions in order, ignoring the ones that are inapplicable in a given state: transport 2 missionaries, transport 1 missionary, transport 1 missionary and 1 cannibal, transport 1 cannibal, transport 2 cannibals. Make sure to ignore illegal states, i.e., states where cannibals outnumber missionaries on either river bank.

(b) What is the result of applying depth-first search (without depth limit)? Justify your answer.

Exercise 4.2 (2.5+2.5 marks)

(a) Consider the heuristic h_1 for the "missionaries and cannibals" problem where

$$h_1(\langle m, c, b \rangle) := \max\{m + c - b, 0\}.$$

(See above for an explanation of the notation.)

Determine if h_1 is *safe*, *goal-aware*, *admissible* and/or *consistent*. Justify your answer for each property.

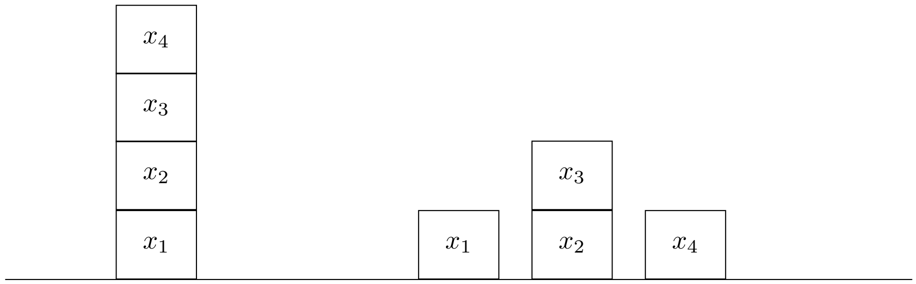
(b) Let $x_1, \dots, x_n$ denote the blocks in a blocks world problem. Consider the heuristic

$$h_2(s) := \sum_{i=1}^{n} f(x_i)$$

for blocks world, where the function f is defined as:

$$f(x_i) := \begin{cases} 1 + |\{x_j \mid x_j \text{ is anywhere above } x_i\}| & \text{if } \mathit{goalpos}(x_i) \neq \mathit{pos}(s, x_i) \\ 0 & \text{otherwise.} \end{cases}$$

The expression $\mathit{goalpos}(x_i) \neq \mathit{pos}(s, x_i)$ holds if block x_i is on block y in state s, but should be on block $z \neq y$ in the goal (as discussed in the lecture, y and z may also represent the table). The heuristic h_2 hence determines all blocks that are not yet at their goal position and adds all blocks above those blocks (since they have to be moved before those blocks can be moved). To illustrate the heuristic, consider the following example:



The initial state s_0 is depicted on the left side, and the goal state on the right. The heuristic value in the initial state is $h_2(s_0) = 0 + 3 + 0 + 1 = 4$ as x_1 and x_3 are on the correct block already and hence $f(x_1) = f(x_3) = 0$. Block x_2 is on x_1 instead of the table with 2 blocks above x_2, so $f(x_2) = 3$, and block x_4 is on x_3 instead of the table and there are no blocks above x_4, so $f(x_4) = 1$.

Determine if h_2 is *safe*, *goal-aware*, *admissible* and/or *consistent*. Justify your answer for each property.

Exercise 4.3 (2+2 marks)

Show that the following two statements do not hold in general:

(a) If a heuristic is admissible, it is also consistent.

(b) If a heuristic is consistent, it is also admissible.

Hint: For each statement it suffices to present a counterexample consisting of a state space and a heuristic operating on this state space for which the left side of the statement holds, but the right side does not. In both cases counterexamples containing at most three states can be found.

Important: The exercise sheets can be submitted in groups of two students. Please provide both student names on the submission.