Foundations of Artificial Intelligence

M. Helmert, M. Wehrle
T. Keller
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University of Basel
Computer Science

Exercise Sheet 11

Due: May 20, 2016

Exercise 11.1 (0.5+0.5+2+1+1+1 marks)

Consider the STRIPS planning task $\Pi = \langle V, I, G, A \rangle$ with $V = \{a, b, c, d, e, f\}$, $I = \{a, b\}$, $G = \{e, f\}$, and $A = \{a_1, a_2, a_3\}$ with $cost(a) = 1$ for all $a \in A$ and

$$\begin{array}{lll} pre(a_1) = \{a\} & add(a_1) = \{c\} & del(a_1) = \{e\} \\ pre(a_2) = \{b\} & add(a_2) = \{d\} & del(a_2) = \{c\} \\ pre(a_3) = \{c, d\} & add(a_3) = \{e, f\} & del(a_3) = \{\}. \end{array}$$

Compute the following and justify your answers:

(a) the STRIPS heuristic $h^S(I)$

(b) the cost of an optimal relaxed plan $h^+(I)$

(c) the relaxed planning graph for Π up to depth 3

(d) the maximum heuristic $h^{\max}(I)$

(e) the additive heuristic $h^{\text{add}}(I)$

(f) the FF heuristic $h^{\text{FF}}(I)$

Exercise 11.2 (2+1+1+1+1 marks)

Consider a planning task where an agent aims to raise a treasure. To do so, the agent must collect a key and use it to open the chest that contains the treasure. Let the problem be formalized in the SAS^+ formalism as $\Pi = \langle V, \text{dom}, I, G, A \rangle$, where

- $V = \{loc, key, trs\}$ is the set of variables with $\text{dom}(loc) = \{A, B, C\}$, $\text{dom}(key) = \{\top, \bot\}$, and $\text{dom}(trs) = \{\top, \bot\}$;
- $I = \{loc \mapsto B, key \mapsto \bot, trs \mapsto \bot\}$ is the initial state;
- $G = \{key \mapsto \top, trs \mapsto \top\}$ is the goal description; and
- $A = \{move_{A,B}, move_{B,A}, move_{B,C}, move_{C,B}, take, open\}$ is the set of actions with

$$\begin{array}{lll} pre(move_{A,B}) = \{loc \mapsto A\} & eff(move_{A,B}) = \{loc \mapsto B\} & cost(move_{A,B}) = 3 \\ pre(move_{B,A}) = \{loc \mapsto B\} & eff(move_{B,A}) = \{loc \mapsto A\} & cost(move_{B,A}) = 3 \\ pre(move_{B,C}) = \{loc \mapsto B\} & eff(move_{B,C}) = \{loc \mapsto C\} & cost(move_{B,C}) = 3 \\ pre(move_{C,B}) = \{loc \mapsto C\} & eff(move_{C,B}) = \{loc \mapsto B\} & cost(move_{C,B}) = 3 \\ pre(take) = \{key \mapsto \bot, loc \mapsto A\} & eff(take) = \{key \mapsto \top\} & cost(take) = 1 \\ pre(open) = \{key \mapsto \top, loc \mapsto C\} & eff(open) = \{trs \mapsto \top\} & cost(open) = 1 \end{array}$$

(a) Provide the state space as a graph and mark the initial state and all goal states (it consists of 12 states, some of which are not reachable from the initial state). For each state, provide the values of all variables, e.g., in the form $B\bot\bot$ for the initial state and accordingly for other states.

(b) Compute the projection of Π to $P = \{loc, trs\}$ (i.e., the variable *key* is ignored). Give the abstraction that is induced by P by providing the abstract state space in the same way as in Exercise 11.2 (a).

(c) Compute the projection of Π to $P' = \{key, trs\}$ (i.e., the variable *loc* is ignored). Give the abstraction that is induced by P' by providing the abstract state space in the same way as in Exercise 11.2 (a).

(d) Use the abstraction from Exercise 11.2 (b) to derive a pattern database heuristic. Provide the database entries (i.e., the abstract distances for all states in the abstract state space) and use them to assign a heuristic value to each of the 12 concrete states.

(e) Use the abstraction from Exercise 11.2 (c) to derive a pattern database heuristic. Provide the database entries (i.e., the abstract distances for all states in the abstract state space) and use them to assign a heuristic value to each of the 12 concrete states.

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