AI 1 2022/23
Assignment12: Planning
– Given Feb 2 –

Problem 12.1 (STRIPS Planning) 0 pt

Consider the road map of Australia given below. The task here is to visit Darwin, Brisbane and Perth, starting from Sydney.

The task is formalized in STRIPS as follows. Facts are $at(x)$ and $visited(x)$ where $x \in \{Adelaide, Brisbane, Darwin, Perth, Sydney\}$. The initial state is $\{at(Sydney), visited(Sydney)\}$, the goal is $\{visited(Brisbane), visited(Darwin), visited(Perth)\}$. The actions move along the roads, i.e., they are of the form

$$drive(x, y) : (\{at(x)\}, \{at(y), visited(y)\}, \{at(x)\})$$

where x and y have a direct connection according to the road map. **Each road can be driven in both directions, except for the road between Adelaide and Perth, which can only be driven from Adelaide to Perth, not in the opposite direction.** In your answers to the following questions, use the abbreviations "v" for "visited", and "Ad", "Br", "Da", "Pe", "Sy" for the cities.

(a) Give an optimal (shortest) plan for the initial state, if one exists; if no plan exists, argue why that is the case. Give an optimal (shortest) relaxed plan for the initial state, if one exists; if no relaxed plan exists, argue why that is the case. What is the h^* value and the h^+ value of the initial state? (When writing up a plan or relaxed plan, it suffices to give the sequence of action names.)

(b) Do the same as in (a) in the modified task where the road between Sydney and Brisbane is also one-way, i.e., it can only be driven from Sydney to Brisbane, not in the opposite direction.

(c) Write up, in STRIPS notation, all states reachable from the initial state in at most *two* steps. Start at the initial state, and insert successors. Indicate successor states by edges. Annotate the states with their h^* values as well as their h^+ values.

(d) Do the same as in (c) in the modified task where the road between Sydney and Brisbane is one-way, i.e., it can only be driven from Sydney to Brisbane, not in the opposite direction.

Solution:

(a) Optimal plan: $drive(Sy, Br)$, $drive(Br, Sy)$, $drive(Sy, Ad)$, $drive(Ad, Da)$, $drive(Da, Ad)$, $drive(Ad, Pe)$. Optimal relaxed plan: $drive(Sy, Br)$, $drive(Sy, Ad)$, $drive(Ad, Da)$, $drive(Ad, Pe)$. $h^* = 6, h^+ = 4$.

(b) Optimal plan: Does not exist because we must visit both Brisbane and Perth, but once we moved to either of these two, we cannot get back out again. Optimal relaxed plan: $drive(Sy, Br)$, $drive(Sy, Ad)$, $drive(Ad, Da)$, $drive(Ad, Pe)$. $h^* = \infty, h^+ = 4$.

Problem 12.2 (Admissible Heuristics in Gripper) 0 pt

Consider a problem where we have two rooms, A and B, one robot initially located in room A, and n balls that are also initially located in room A. The goal demands that all balls be located in room B. The robot can move between the rooms, it can pick up balls provided its gripper hand is free (see below), and it can drop a ball it is currently holding.

Answer the following questions with yes/no. Justify your answer.

(a) Say that the robot has only one gripper, so that it can only hold one ball at a time. Is the number of balls not yet in room B an admissible heuristic function?

(b) Say that the robot has only one gripper, so that it can only hold one ball at a time. Is the number of balls still in room A, multiplied by 4, an admissible heuristic function?

(c) Say now the robot has two grippers, and it takes only one action to pick up two balls, and only one action to drop two balls. Is the number of balls not yet in room B an admissible heuristic function?

(d) Say now the robot has two grippers, but picks up/drops each ball individually, so that it needs two actions to take two balls, and two actions to drop two balls. Is the number of balls not yet in room B an admissible heuristic function?

Solution:

(a) Yes: The solution must contain at least one separate drop action for each ball that is not yet currently in room B.

(b) No: For example, in the initial state for $n = 1$, the length of an optimal solution is 3 (pick, move A B, drop), whereas the value of this heuristic function is 4.

(c) No: For example, if all but 2 balls are already in room B, and the robot is in room B and holds the 2 remaining balls, then the length of an optimal solution is 1, whereas the value of this heuristic function is 2.

(d) Yes, for the same reason as in (a).

Problem 12.3 (Partial Order Planning) 0 pt

Consider partial-order planning.

1. Given a STRIPS task $\Pi := \langle P, A, I, G \rangle$, what are the components of a partially ordered plan?
2. What are the conditions on a partially ordered plan to be complete and consistent?
3. How can we turn such a plan into a solution of the original planning task?

Solution:

1. A partially ordered plan consists of
   - a start node which has the facts in I as a postcondition,
   - a finish node which has the facts in G as a precondition
   - causal links $S \xrightarrow{p} T$ where p is a precondition fulfilled by S
   - temporal ordering constraints $S \prec T$.
2. A partially ordered plan is complete iff all preconditions are achieved by a causal link; and consistent iff the relation induced by causal links and ordering relations is a partial ordering.
3. Any linearization of a complete partially ordered plan is a solution.