Graduate Artificial Intelligence 15-780

Homework 4: *Classical Planning*

Out on March 21st
Due on April 4th

Problem 1: Solving goals independently [Felipe, 30 pts]

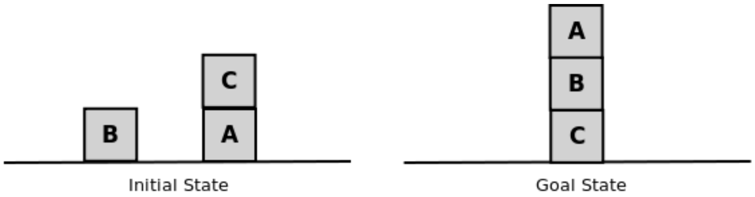

Figure 1: Example of the blocks world for problem 2.

A common example for classical planning is the blocks world (Figure 1). In this domain, we have a set of blocks in a table that we want to move using a robotic arm. Three actions are possible: (i) Pick-up X, that picks up and holds the block X from the table or from the top of a pile of blocks; (ii) Put-down X, that places the block being held by the robot in the table; and (iii) Put-on-top X Y that places the block X on top of Y if the robot is holding X and no block is on top Y (i.e. Y is clear).

a) Show a plan, i.e. a sequence of actions, that can be applied in Figure 1 to reach the goal state from the initial state. [5 pts]

Let's assume for the remainder of this problem that the goal state is given as an ordered list $G = [g_1, g_2, \dots, g_n]$. An example of such goal specification for the problem in Figure 1 is $\big[$(on-table C), (on B C), (on A B)$\big]$. We can see each item as a subgoal and the list as a goal agenda, i.e., first we fulfill g_1, then g_2 and so on. Consider the following strategy to solve a classical planning problem: follow this goal agenda in the given order, never revisit an old goal and declare the problem as solved when the last subgoal g_n is fulfilled. Let's call this strategy the *linear strategy*.

b) Does your plan in (a) respect the linear strategy for the goal given as the list $\big[$(on-table C), (on B C), (on A B)$\big]$ (Figure 1)? If not, give one that satisfies it. [5 pts]

c) Prove that the linear strategy is complete or show a counter-example. [20 pts]

Problem 2: Planning Graph [Felipe, 40pts][1]

a) For the planning graph, prove that a literal that does not appear in the final level of the graph, i.e. when the graph levels off, can not be achieved. [10 pts]

For the remainder of this problem, let's consider the *serial planning graph*, i.e. the special case of the planning graph in which a mutex is added between every pair of non-persistence actions (actions that are not No-Op).

b) Consider the Dinner problem example presented in class (Lecture 16, slide #20). Draw the first three levels (i.e. $c_0, a_1, c_1, \dots, a_3, c_3$ where c_i is the ith level of conditions and a_i is the ith level of actions) of the serial planning graph for this problem. Don't forget to include all the mutexes.[2] [10 pts]

c) What is the serial planning graph enforcing by adding the extra mutexes? [5 pts]

d) Prove that the maximum level cost over all the goal conditions in the serial planning graph is an admissible heuristic or show a counter-example. [15 pts]

[1] Based on problem 10.10 of the course textbook.

[2] To save time, you can draw it by hand and scan it.

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GreedyPlanner-DeleteRelaxation($s_0$: initial state, $s_G$ goal state, $S$ the state space, $A(s)$ the set of actions
applicable in a given state $s$, $T\colon S \times A \rightarrow S$ the transition function, i.e. $T(s,a)$ is the state reached after
applying $a$ in state $s$.)
begin
    $s \leftarrow s_0$
    while $s \neq s_G$ do
        $a \leftarrow \text{argmin}_{a \in A(s)}\{\text{length of the plan from } T(s,a) \text{ to } s_G \text{ in the delete relaxation}\}$
        ExecuteAction($a$)
        $s \leftarrow T(s,a)$
end
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Problem 3: Ignore Delete Relaxation [Felipe, 30pts]

a) Prove that the ignore delete relaxation is an admissible heuristic. [5 pts]

b) Give an example of a problem in which the solution of the ignore delete relaxation does not share any action with the optimal solution of the original problem. Don't forget to specify the initial state, goal state and actions. [10 pts]

c) Suppose we are interested in planning and execution, that is, to execute actions in the world as we plan. Consider Algorithm 1, i.e. the greedy algorithm with respect to the ignore delete relaxation. Prove that this algorithm cannot reach a dead-end (i.e. a state s such that $A(s) = \emptyset$) or give a counter-example. [15 pts]