CMPT 310 Assignment 4 Suggested Solutions

1. [20%] A STRIP formulation of this planning domain is the following:

Constants:

Rooms: $v_1, v_2, \ldots, v_n$

Artifects: $a_1, a_2, \ldots, a_m$

Predicates:

- link(*room1*, *room2*): There is a corridor between *room1* and *room2*, allowing the agent to move from *room1* to *room2*.
- empty(*room*): No artifect is currently residing in *room*.
- in(*artifect*, *room*): *Artifect* is currently located in *room*.
- agent(*room*): The agent is currently in *room*.

Operators:

- navigate(*room1*, *room2*):
  preconditions: agent(*room1*), link(*room1*, *room2*)
  delete-list: agent(*room1*)
  add-list: agent(*room2*)
- carry(*artifect*, *room1*, *room2*):
  preconditions: in(*artifect*, *room1*), agent(*room1*), link(*room1*, *room2*)
  delete-list: in(*artifect*, *room1*), agent(*room1*)
  add-list: in(*artifect*, *room2*), agent(*room2*)

Initial Situation:

- in(a_1, v_1), in(a_2, v_2), ... , in(a_m, v_m)
- empty(v_{m+1}), empty(v_{m+2}), ... , empty(v_n)
- agent(v_n)
- link(v_i, v_j), link(v_j, v_i) for each each edge in graph.

Goals:

- in(a_1, v_n), in(a_2, v_{n-1}), ... , in(a_m, v_{n-m+1})

2. [20%] Suppose a partial order plan contains, among other things, a causal link $S_1 \xrightarrow{p(a,x)} S_2$ and a step S_3 that deletes $p(y,z)$ and requires $q(y)$ as a precondition, where x, y and z are variables.

(a) $b = \{y = a, z = x\}$

(b)

Promotion: impose both b and $S_3 < S_1$

Demotion: impose both b and $S_2 < S_3$

Separation (1): impose $\{y \neq a\}$

Separation (2): impose $\{y = a, z \neq x\}$

(c) The binding that will make S_3 threaten $S_4 \xrightarrow{q(y)} S_3$ is the following:

$$b' = \{z = x\}$$

The threat can be removed in one of the following ways:

Promotion: impose both b' and $S_3 < S_1$

Demotion: impose both b' and $S_2 < S_3$

Separation: impose $\{z \neq x\}$

(d) If we remove the separable threat $\langle S_3, b, S_1 \xrightarrow{p(a,x)} S_2 \rangle$ as soon as it comes into existence, the local branching factor will be 4. However, if we delay the removal of this threat, the introduction of S_4 will make some of the binding possibilities go away. As a result, the branching factor of removing the threat $\langle S_3, b', S_1 \xrightarrow{p(a,x)} S_2 \rangle$ becomes 3.

3. (a) [10%]

Criticality	Preconditions
2	in(*artifect*, *room*), link(*room1*, *room2*)
1	empty(*room*)
0	agent(*room*)

(b) [10%] Suppose the number of rooms is exactly the same as the number of artifects. Then the artifects cannot be moved. The planning problem becomes unsolvable at the concrete level (i.e. level 0). However, the problem has a solution at abstraction level 2, because the colocation constraint is ignored. As a result, the Downward Refinement Property, which guarantees that abstraction solutions can always be refined to concrete solutions, is violated.

4. [20%]

(a) [4%] Define f to be the identity function: $f(i) = i$ for all $i \in S$. In this case, A_i takes q_i as the only precondition and deletes q_i while adding p_i.

(b) [6%] Let A_i and A_j be two distinct operators (i.e. $i \neq j$). If A_i deletes q_j, which is a precondition of A_j, then a solution plan with all threats removed will have $A_j < A_i$ (by demotion). Now, if there is a series $i_1, i_2, \ldots, i_k \in S$ so that $k > 1$ and $i_1 = f(i_2), i_2 = f(i_3), \ldots, i_{k-1} = f(i_k)$ and $i_k = f(i_1)$, then there will be no consistent way of removing all the threats[1]. In fact, fixing a definition of f, the non-existence of such series is the necessary and sufficient condition for the planning problem to be solvable.

(c) [4%] The abstract problem is always solvable no matter what f is defined.

[1]To remove the threats among $A_{i_1}, A_{i_2}, \ldots, A_{i_k}$, we will need to impose the ordering constraints $A_{i_1} < A_{i_2} < \ldots < A_{i_k} < A_{i_1}$, which are inconsistent. Notice also that the requirement of $k > 1$ is significant, as the solution for part (a) indicates.

(d) [6%] The Downward Refinement Property requires that the existence of an abstract solution plan implies the existence of a concrete solution plan that is a refinement of the abstract plan. In this problem, an abstract plan always exists (see (c)), but the existence of a concrete solution plan depends on the definition of f. If such concrete plan exists, it is guaranteed to be a refinement of the abstract plan. Therefore, the Downward Refinement Property is satisfied if and only if f is defined in a way that the concrete problem is solvable. As a result, the necessary and sufficient condition for the Downward Refinement Property to hold is exactly the condition outlined in part (b).

5. (a) [10%] See the web site given in the statement of the problem for an outline of the solution.

   (b) [10%] Mechanical.