# 50.021 – Artificial Intelligence

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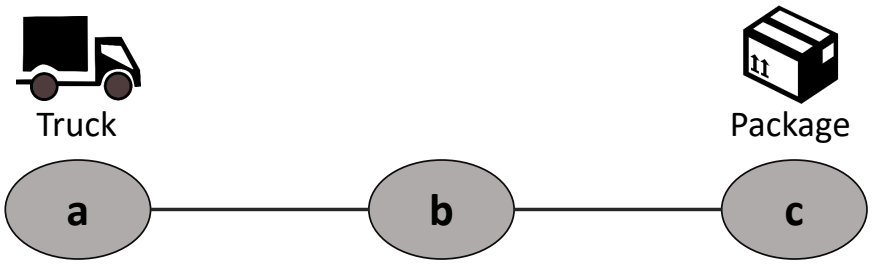
Week 11 Theory Homework - Planning

[The following notes are compiled from various sources such as textbooks, lecture materials, Web resources and are shared for academic purposes only, intended for use by students registered for a specific course. In the interest of brevity, every source is not cited. The compiler of these notes gratefully acknowledges all such sources. ]

These answers are provided only as a brief guide. There could be more than one way to answer the questions.

## 1 Logistic Problem I

Consider the following logistic problem. There are three locations $a$, $b$ and $c$, with a truck at $a$ and package at $c$. The truck is able perform the following actions: (i) move(x,y): move from location $x$ to $y$; (ii) load(x): load a package at location $x$; and (iii) unload(x): unload the package at location $x$. The truck can only move between adjacent locations, e.g., $a$ to $b$, $b$ to $c$ (You can assume that these static facts are already modelled/defined).




Given the start state in the above diagram, your goal is to get the package to location $b$. Formulate this logistic problem using the STRIPS representation and answer the following:
a.) List down the propositional variables (facts).
b.) Specify the operators (actions), including the pre-conditions and post-conditions.
c.) Specify the initial state.
d.) List down the goal state/specification.

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Q1 Answers:

a.) Facts: truckAt(x), packAt(x), packInTruck

b.)
     (:action   move(x,y)
          :preconditions   truckAt(x)
          :postconditions   not truckAt(x), truckAt(y)
     )
     (:action   load(x)
          :preconditions   truckAt(x), packAt(x)
          :postconditions   not packAt(x), packInTruck
     )
     (:action   unload(x)
          :preconditions   truckAt(x), packInTruck
          :postconditions   packAt(x), not packInTruck
     )

c.) Initial State:  truckAt(a), packAt(c)

d.) Goal State: packAt(b)
```

# 2 Logistic Problem II

Based on your STRIPS formulation from Q1 (Logistic Problem I), answer the following:
a.) What is the optimal solution to this problem?
b.) Make this a delete-relaxed problem. What are the changes to the original STRIPS formulation you made?
c.) Based on this delete-related problem, list down all the facts $F_x$ and actions $A_x$ at levels $x = \{0, 1, ..., M\}$.

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Q2: Answers:

a.) move(a,b), move(b,c), load(c), move(c,b), unload(b)

b.) any answer that removes all delete postconditions from the actions

c.)
F0: truckAt(a), packAt(c)
A0: move(a,b)
F1: truckAt(a), packAt(c), truckAt(b)
A1: move(b,c) [also ok if move(b,a) is listed]
F2: truckAt(a), packAt(c), truckAt(b), truckAt(c)
A2: load(c) [also ok if move(c,b) is listed]
F3: truckAt(a), packAt(c), truckAt(b), truckAt(c), packInTruck
A3: unload(a), unload(b), unload(c)
F4: truckAt(a), packAt(c), truckAt(b), truckAt(c), packInTruck, packAt(a), packAt(b)
```

# 3 Logistic Problem III

Based on your answer from Q2 (Logistic Problem II), answer the following:
a.) What is the optimal solution to this delete-relaxed problem? What is this heuristic called?
b.) What is the value of $h_{add}$? Explain why.
c.) What is the value of $h_{max}$? Explain why.

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Q3: Answers

a.) move(a,b), move(b,c), load(c), unload(b). This is the h+ heuristic.

b.) h_add = 4. Adds cost of all goal facts up. In this case, there is only
     1 goal fact, packAt(b), which is reached at F4 (see Q2c).

c.) h_max = 4. Max cost out of all goal facts. In this case, there is only
     1 goal fact, packAt(b), which is reached at F4 (see Q2c).
```

# 4 Generic Planning I

Consider a STRIPS problem with propositional variables (facts) $m, n, o, p$, and the below STRIPS actions with their pre/post-conditions.

| Action | Pre | Add | Del |
|---|---|---|---|
| A | m | n,o | $\emptyset$ |
| B | m,o | p | m |
| C | p | m | p |
| D | n,o | p | o |

Given an initial state $s = \{m\}$ and goal specification $g = \{m, n, o, p\}$, answer the following questions:
a.) What is the value of $h_+$? Explain why.
b.) What is the value of $h_{add}$? Explain why.
c.) What is the value of $h_{max}$? Explain why.

```
Q4: Answers:

F0: m
A0: A
F1: m, n, o
A1: B, D
F2: m, n, o, p

a.) h+ = 2. Solution (cost) to delete-relaxed version of problem (see above facts and actions)

b.) h_add = 4. Adding up cost of all goal facts, i.e., 0+1+1+2.

c.) h_max = 2. Max cost of all goal facts, i.e., 2
```

# 5 Generic Planning II

Based on the same STRIPS formulation in Q4 (Generic Planning I). Now, based on initial state $s = \{p\}$ and goal specification $g = \{m, n, o, p\}$, answer the following questions:
a.) What is the value of $h_+$ (if any)? Explain why.
b.) What is the value of $h_{add}$ (if any)? Explain why.
c.) What is the value of $h_{max}$ (if any)? Explain why.

```
Q5: Answers:

F0: p
A0: C
F1: p, m
A1: A
F2: p, m, n, o

a.) h+ = 2. Solution (cost) to delete-relaxed version of problem (see above facts and actions)

b.) h_add = 5. Adding up cost of all goal facts, i.e., 0+1+2+2.

c.) h_max = 2. Max cost of all goal facts, i.e., 2
```