SUTD 50.021 AI

Week 11 Theory Homework - Planning

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Question 1: Logistic Problem I

1. **STRIPS representation:**
   - **P**: Set of propositional variables
     - onA(truck): truck is on location a
     - onB(truck): truck is on location b
     - onC(truck): truck is on location c
     - onA(package): unloaded package is on location a
     - onB(package): unloaded package is on location b
     - onC(package): unloaded package is on location c
     - truckloaded: the truck is holding a package
   - **O**: A set of operators(actions):
     - move(A,B): move truck from location a to b:
       - pre_a: onA(truck)
       - add_a: onB(truck)
       - del_a: onA(truck)
     - move(B,C): move truck from location b to c:
       - pre_a: onB(truck)
       - add_a: onC(truck)
       - del_a: onB(truck)
     - move(C,B): move truck from location c to b:
       - pre_a: onC(truck)
       - add_a: onB(truck)
       - del_a: onC(truck)
     - move(B,A): move truck from location b to a:
       - pre_a: onB(truck)
       - add_a: onA(truck)
       - del_a: onB(truck)
     - load(A): truck loads a package at location a:
       - pre_a: onA(truck), onA(package)
       - add_a: truckloaded
       - del_a: onA(package)
     - load(B): truck loads a package at location b:
       - pre_a: onB(truck), onB(package)
       - add_a: truckloaded
       - del_a: onB(package)
     - load(C): truck loads a package at location c:
       - pre_a: onC(truck), onC(package)
       - add_a: truckloaded
       - del_a: onC(package)
     - unload(A): truck unloads a package at location a:

        * pre_a: onA(truck), truckloaded
        * add_a: onA(package)
        * del_a: truckloaded
    - unload(B): truck unloads a package at location b:
        * pre_a: onB(truck), truckloaded
        * add_a: onB(package)
        * del_a: truckloaded
    - unload(C): truck unloads a package at location c:
        * pre_a: onC(truck), truckloaded
        * add_a: onC(package)
        * del_a: truckloaded
- **I**: Initial state of the world
    - onA(truck), onC(package)
- **G**: Goal state of the world
    - onB(truck), onB(package)

Question 2: Logistic Problem II

1. Optimal solution: move(A,B), move(B,C), load(C), move(C,B), unload(B)
2. Deleted-relaxed problem, by removing all the negation of facts in all operators (remove all del_a):
    - **P**: Set of propositional variables
        - onA(truck): truck is on location a
        - onB(truck): truck is on location b
        - onC(truck): truck is on location c
        - onA(package): unloaded package is on location a
        - onB(package): unloaded package is on location b
        - onC(package): unloaded package is on location c
        - truckempty: the truck is not holding any package
    - **O**: A set of operators(actions):
        - move(A,B): move truck from location a to b:
            * pre_a: onA(truck)
            * add_a: onB(truck)
        - move(B,C): move truck from location b to c:
            * pre_a: onB(truck)
            * add_a: onC(truck)
        - move(C,B): move truck from location c to b:
            * pre_a: onC(truck)
            * add_a: onB(truck)
        - move(B,A): move truck from location b to a:
            * pre_a: onB(truck)
            * add_a: onA(truck)
        - load(A): truck loads a package at location a:
            * pre_a: onA(truck), onA(package)
            * add_a: truckloaded
        - load(B): truck loads a package at location b:
            * pre_a: onB(truck), onB(package)
            * add_a: truckloaded
        - load(C): truck loads a package at location c:
            * pre_a: onC(truck), onC(package)
            * add_a: truckloaded
        - unload(A): truck unloads a package at location a:
            * pre_a: onA(truck), truckloaded
            * add_a: onA(package)
        - unload(B): truck unloads a package at location b:

        * pre_a: onB(truck), truckloaded
        * add_a: onB(package)
      - unload(C): truck unloads a package at location c:
        * pre_a: onC(truck), truckloaded
        * add_a: onC(package)
  - **I**: Initial state of the world
    - onA(truck), onC(package), truckempty
  - **G**: Goal state of the world
    - onB(truck), onB(package), truckempty
3. Concise representation:
  - Variables: onA(truck), onB(truck), onC(truck), onA(package), onB(package), onC(package), truckloaded
  - Initial State: onA(truck), onC(package)
  - Goal: onB(truck), onB(package)
  - Actions:
    - o_1: *pre*: onA(truck) | *post*: onB(truck)
    - o_2: *pre*: onB(truck) | *post*: onC(truck)
    - o_3: *pre*: onC(truck) | *post*: onB(truck)
    - o_4: *pre*: onB(truck) | *post*: onA(truck)
    - o_5: *pre*: onA(truck), onA(package) | *post*: truckloaded
    - o_6: *pre*: onB(truck), onB(package) | *post*: truckloaded
    - o_7: *pre*: onC(truck), onC(package) | *post*: truckloaded
    - o_8: *pre*: onA(truck), truckloaded | *post*: onA(package)
    - o_9: *pre*: onB(truck), truckloaded | *post*: onB(package)
    - o_{10}: *pre*: onC(truck), truckloaded | *post*: onC(package)
  - Facts and actions:
    - F_0: onA(truck), onC(package)
    - A_0: o_1
    - F_1: onA(truck), onB(truck), onC(package)
    - A_1: o_2
    - F_2: onA(truck), onB(truck), onC(truck), onC(package)
    - A_2: o_7
    - F_3: onA(truck), onB(truck), onC(truck), onC(package), truckloaded
    - A_3: o_9
    - F_4: onA(truck), onB(truck), onC(truck), onB(package), onC(package), truckloaded

Question 3: Logistic Problem III

1. Optimal solution to delete relaxed problem: o_1: move(A,B), o_2: move(B,C), o_7: load(C), o_9: unload(B). Note the optimal number of steps for relaxed problem is 4 which is less than the optimal number to original problem of 5, hence admissible. This heuristic is called `h+ heuristics`.
2. h_{add} is $1 + 4 = 5$, summed cost (number of steps) of all the goal facts (in bold).
  - F_0: onA(truck), onC(package)
  - A_0: o_1
  - F_1: onA(truck), **onB(truck)**, onC(package)
  - A_1: o_2
  - F_2: onA(truck), onB(truck), onC(truck), onC(package)
  - A_2: o_7
  - F_3: onA(truck), onB(truck), onC(truck), onC(package), truckloaded
  - A_3: o_9
  - F_4: onA(truck), onB(truck), onC(truck), **onB(package)**, onC(package), truckloaded
3. h_{max} is 4, the cost of the single most costly goal fact (**onB(package)**).

Question 4: Generic Planning I

Assumption: Delete-relaxed problem (no delete actions), therefore firstly remove all deletes.

1. $h+$ is 2 (A -> B/D to achieve goal state of m, n, o, p), the minimal number of actions for a delete-relaxed problem (no deletes).
2. h_{add} is $0 + 1 + 1 + 2 = 4$, summed cost (number of steps) of all the goal facts (in bold).
   - F_0: **m**
   - A_0: A
   - F_1: m, **n**, **o**
   - A_1: B or D
   - F_2: m, n, o, **p**
3. h_{max} is 2, the cost of the single most costly goal fact (**p**).

Question 4: Generic Planning II

Assumption: Delete-relaxed problem (no delete actions), therefore firstly remove all deletes.

1. $h+$ is 2 (C -> A to achieve goal state of m, n, o, p), the minimal number of actions for a delete-relaxed problem (no deletes).
2. h_{add} is $0 + 1 + 2 + 2 = 5$, summed cost (number of steps) of all the goal facts (in bold).
   - F_0: **p**
   - A_0: C
   - F_1: **m**, p
   - A_1: A
   - F_2: m, **n**, **o**, p
3. h_{max} is 2, the cost of the single most costly goal fact (**n** or **o**).