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Task 1

Tower of Hanoi

Problem 1

```
initial state:
(on disk1 disk2)
(on disk2 A)
(clear disk1)
(clear B)
(clear C)

goal:
(on disk1 B)
(on disk2 C)
```

Problem 2

```
initial state:
(on disk1 disk2)
(on disk2 disk3)
(on disk3 disk4)
(on disk4 disk5)
(on disk5 C)
(clear disk1)
(clear A)
(clear B)

goal:
(on disk1 disk2)
(on disk2 disk3)
(on disk3 disk4)
(on disk4 disk5)
(on disk5 A)
```

Notes: This has been solved and can be executed using the following commands:

- For executing problem 1:
  ./graphplan -o tower_of_hanoi/ops.txt -f tower_of_hanoi/facts1.txt

- For executing problem 2:
  ./graphplan -o tower_of_hanoi/ops.txt -f tower_of_hanoi/facts2.txt

7-puzzle Description

Problem 1

```
initial state:
123
X56
4X7
```

```
goal:
123
456
7XX
```

Problem 2

```
initial state:
XX7
654
321

goal:
123
456
7XX
```

Notes: This has been solved and can be executed using the following commands:

- For executing problem 1:
  ./graphplan -o 7_puzzle/ops.txt -f 7_puzzle/facts1.txt

- For executing problem 2:
  ./graphplan -o 7_puzzle/ops.txt -f 7_puzzle/facts2.txt

Task 2

Two adults and two children are on the left side of the river. Each adult weighs 150 pounds. Each child has half the weight of an adult, so each child weighs 75 pounds. They all want to cross to the right side of the river. However, the only means of transportation they can use is a boat, and the boat can carry a maximum of 150 pounds. Thus, the boat can carry one adult without children, or one child, or two children. Any adult or child can operate the boat, but the boat cannot be operated without having at least one person on the boat. The goal is to come up with a plan for moving everyone from the left side to the right side using multiple boat trips.

Describe the initial state and the goal, using PDDL. Define appropriate actions for this planning problem, in the PDDL language. For each action, provide a name, arguments, preconditions, and effects. Also, give a complete plan (using the actions described) for getting from the start to the goal state

Constants:

```
(A1 Adult)
(A2 Adult)
(C1 Child)
(C2 Child)
(L Location)
(R Location)
(B Boat)
```

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Initial State:

```
(on A1 L) AND (on A2 L) AND (on C1 L) AND (on C2 L) AND (on B L)
```

Goal State:

```
(on A1 R) AND (on A2 R) AND (on C1 R) AND (on C2 R)
```

Actions

```
(operator moveAdult
 (params
               (<a> Adult)
               (<loc1> Location)
               (<loc2> Location))
 (preconds
               (on <a> <loc1>) AND (on B <loc1>))
 (effects
               (on <a> <loc2>) AND (on B <loc2>) AND (del on <a> <loc1>)
                      AND (del on B <loc1>)))

(operator moveChild
 (params
               (<a> Child)
               (<loc1> Location)
               (<loc2> Location))
 (preconds
               (on <a> <loc1>) AND (on B <loc1>))
 (effects
               (on <a> <loc2>) AND (on B <loc2>) AND (del on <a> <loc1>)
                      AND (del on B <loc1>)))

(operator moveChildren
 (params
               (<a> Child)
               (<b> Child)
               (<loc1> Location)
               (<loc2> Location))
 (preconds
               (on <a> <loc1>) AND (on <b> <loc1>) AND (on B <loc1>))
 (effects
               (on <a> <loc2>) AND (on <b> <loc2>) AND (on B <loc2>)
                      AND (del on <a> <loc1>) AND (del on <b> <loc1>)
                      AND (del on B <loc1>)))
```

Plan:

```
1 moveChildren_C2_C1_L_R
2 moveChild_C2_R_L
3 moveAdult_A1_L_R
4 moveChild_C1_R_L
5 moveChildren_C2_C1_L_R
6 moveChild_C2_R_L
7 moveAdult_A2_L_R
8 moveChild_C1_R_L
9 moveChildren_C2_C1_L_R
```

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Note: The following can be seen by using the command:

./graphplan -o task2_boat/ops.txt -f task2_boat/facts.txt

Task 3

Consider the problem in Task 2. Let us say that, if there is only one person in the boat, the boat can be blown off course and end up back on the side it originally started from. How would you modify the actions you described in Task 2 to account for this if you were going to try and handle this scenario by

- ***Execution Monitoring/Online Replanning***
- ***Conditional Planning***

In both cases, show what the modifications are (If no modification is necessary, Justify).

For Online Replanning, there is no need to make any modifications as it would replan the complete scenario. If the goal of an action is not achieved, then the system replans the flow again from the current state.

For Conditional Planning or Contingent Planning, we need to modify the following actions:

Actions:

```
(operator moveAdult
 (params
               (<a> Adult)
               (<loc1> Location)
               (<loc2> Location))
 (preconds
               (on <a> <loc1>) AND (on B <loc1>))
 (effects
               ((on <a> <loc2>) AND (on B <loc2>) AND (del on <a> <loc1>)
                      AND (del on B <loc1>)) OR ( True ))

(operator moveChild
 (params
               (<a> Child)
               (<loc1> Location)
               (<loc2> Location))
 (preconds
               (on <a> <loc1>) AND (on B <loc1>))
 (effects
               ((on <a> <loc2>) AND (on B <loc2>) AND (del on <a> <loc1>)
                      AND (del on B <loc1>)) OR ( True ))
```

Task 4

We have state descriptions and action definitions written following the conventions used in the graphplan software of Task 1. One of the actions is defined as follows:

```
(operator
 aaa
 (params
 (<b> ttt1) (<c> ttt1))
 (preconds
 (ppp1 <b> <c>) (ppp2 <b>) (ppp3 <c>))
 (effects
 (eee1 <b> <c>) (eee2 <b>) (del eee2 <c>) (del eee3 <c>)))
```

Suppose we are at a state S1 described as follows (again, using graphplan syntax):

```
(A ttt1)
(B ttt1)
(C ttt1)
(ppp1 B C)
(ppp2 A)
(ppp2 B)
(ppp3 C)
(eee1 A C)
(eee2 C)
(eee3 C)
(eee3 A)
```

What is the state resulting from applying action aaa(B,C) to S1? Give a complete specification.

We see that for the action ‘aaa’, two paramters B, C satisfy all the preconditions. That is: (ppp1 B C) AND (ppp2 B) AND (ppp3 C). Thus it generates the following literals at S1: (eee1 B C) AND (eee2 B). S1 also deletes the following literals: (eee2 C) AND (eee3 C). Thus the complete state being:

```
(A ttt1)
(B ttt1)
(C ttt1)
(ppp1 B C)
(ppp2 A)
(ppp2 B)
(ppp3 C)
(eee1 A C)
(eee3 A)
(eee1 B C)
(eee2 B)
```

Note: This can seen as only one move is generated by running the following command

./graphplan -o task4_states/ops.txt -f task4_states/facts.txt

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Task 5

Suppose that we are using PDDL to describe facts and actions in a certain world called JUNGLE. In the JUNGLE world there are 4 predicates, each predicate takes at most 3 arguments, and there are 5 constants. Give a reasonably tight bound on the number of unique states in the JUNGLE world.

Number of Constants: 5
Number of predicates = 4
Number of Arguments each predicate can take: 3

Number of arguments all four predicates can have = 3 * 4 = 12

Number of unique states = 5^{12}

References:

- http://vlm1.uta.edu/~athitsos/courses/cse4308_fall2016/lectures/04b_real_world_planning.pdf