Artificial intelligence - Project 3
- Classical Planning -

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1 Problem

Există un set de voluntari, fiecare putând transporta maxim 3 bucăți de material radioactiv. Acești voluntari trebuie chemați să meargă în centrala nucleară pentru a curăța o anumită zonă din reactor sau pentru a căra afară bucăți de material radioactiv. Pentru a le asigura siguraţa, la locul acţiunilor trebuie să fie prezentă minim o ambulanţă, pentru a duce la spital voluntarii grav afectaţi.Când o ambulanţă pleacă cu un pacient, alta este chemată. Centrala este încă în stare de risc, de aceea va intra câte un voluntar odată. Unii voluntari nu doresc ca anumite persoane să lucreze după ei. Structura reactorului este reprezentată de un grafic aciclic neorientat. Voluntarii au un singur punct de intrare. Anumite zone ale reactorului necesită curăţare de substanţa depusă. Deplasarea și curăţarea anumitor zone determină ruperea a aproximativ o bucată de material radioactiv din cauza călcării pe acestea. Voluntarii trebuie să iasă din reactor și să primească îngrijirile necesare. Din cauza undelor la care sunt dispuși, aceștia au voie să participe la o singură operaţiune.

1.1 Domain file

```
1   (define (domain chernobyl-operation)
2       (:requirements :strips :action-costs)
3       (:types zone volunteer ambulance radioactiveMaterial quantity)
4       (:predicates
5           (localized ?mat - radioactiveMaterial)
6           (full ?mat - radioactiveMaterial)
7           (capacity ?v - volunteer ?q - quantity)
8           (next-material ?mat1 - radioactiveMaterial ?mat2 - radioactiveMaterial)
9           (at-volunteer ?v - volunteer ?z - zone)
10          (at-material ?mat - radioactiveMaterial ?z - zone)
11          (available ?v - volunteer)
12          (in-reactor)
13          (reactor-entrance ?z - zone)
14          (out ?v - volunteer)
15          (health-care ?v - volunteer)
16          (extra-health-care ?v - volunteer)
17          (connected ?z1 - zone ?z2 - zone)
18          (precludes ?v1 - volunteer ?v2 - volunteer)
19          (next-quantity ?q1 - quantity ?q2 - quantity)
20          (holding ?v - volunteer ?mat - radioactiveMaterial)
21          (clean ?z - zone)
22          (occupied ?a - ambulance ?v - volunteer)
23          (prezent ?a-ambulance)
24          (exhausted ?v - volunteer)
25      )
26
27      (:functions
28          (total-cost) - number
29      )
30
31      (:action call-volunteer
32          :parameters (?v1 - volunteer)
33          :precondition   (and(available ?v1)
34                              (not (in-reactor))
35                          )
36          :effect (and(out ?v1)
37                      (not (available ?v1))
```

```
38              (forall (?v2 - volunteer)
39              (when (precludes ?v1 ?v2) (not (available ?v2)))))
40              (in-reactor)
41              (increase (total-cost) 1)
42          )
43      )
44
45      (:action call-ambulance
46          :parameters (?a1 ?a2 - ambulance ?v - volunteer)
47          :precondition   (and(occupied ?a2 ?v )
48                          (not (prezent ?a1))
49                      )
50          :effect (and(prezent ?a1)
51                      (increase (total-cost) 1)
52                  )
53      )
54
55      (:action localize-radioactive-material
56          :parameters (?v - volunteer ?mat1 ?mat2 - radioactiveMaterial ?q1 ?q2 - quantity)
57          :precondition   (and(out ?v)
58                          (localized ?mat1)
59                          (next-quantity ?q1 ?q2)
60                          (capacity ?v ?q2)
61                          (next-material ?mat1 ?mat2)
62                      )
63          :effect (and(not (localized ?mat1))
64                  (not (capacity ?v ?q2))
65                  (localized ?mat2)
66                  (full ?mat1)
67                  (capacity ?v ?q1)
68                  (holding ?v ?mat1)
69                  (increase (total-cost) 1)
70
71              )
72      )
73
74      (:action enter-reactor
75          :parameters (?v - volunteer ?z - zone)
76          :precondition   (and(out ?v)
77                          (reactor-entrance ?z)
78                      )
79          :effect (and(not (out ?v))
80                  (at-volunteer ?v ?z)
81                  (increase (total-cost) 1)
82              )
83      )
84
85      (:action take-radioactive-material
86          :parameters (?v - volunteer ?mat - radioactiveMaterial ?z - zone ?q1 ?q2 - quantity)
87          :precondition   (and(at-volunteer ?v ?z)
88                          (at-material ?mat ?z)
89                          (next-quantity ?q1 ?q2)
90                          (capacity ?v ?q2)
91                      )
```

```
 92          :effect (and(not (at-material ?mat ?z))
 93                       (not (capacity ?v ?q2))
 94                       (holding ?v ?mat)
 95                       (capacity ?v ?q1)
 96                       (increase (total-cost) 1)
 97                  )
 98      )
 99
100     (:action take-localized-radioactive-material
101         :parameters (?v - volunteer ?mat - radioactiveMaterial ?z - zone ?q1 ?q2 - quantity)
102         :precondition  (and(at-volunteer ?v ?z)
103                            (holding ?v ?mat)
104                            (next-quantity ?q1 ?q2)
105                            (capacity ?v ?q1)
106                        )
107         :effect (and(not (holding ?v ?mat))
108                     (not (capacity ?v ?q1))
109                     (at-material ?mat ?z)
110                     (capacity ?v ?q2)
111                     (increase (total-cost) 1)
112                 )
113     )
114
115     (:action walk
116         :parameters (?v - volunteer ?mat - radioactiveMaterial ?z1 ?z2 - zone)
117         :precondition  (and(at-volunteer ?v ?z1)
118                            (holding ?v ?mat)
119                            (full ?mat)
120                            (connected ?z1 ?z2)
121                        )
122         :effect (and(not (at-volunteer ?v ?z1))
123                     (not (full ?mat))
124                     (at-volunteer ?v ?z2)
125                     (increase (total-cost) 1)
126                 )
127     )
128
129     (:action clean-zone
130         :parameters (?v - volunteer ?z - zone ?mat - radioactiveMaterial)
131         :precondition  (and(at-volunteer ?v ?z)
132                            (holding ?v ?mat)
133                            (full ?mat)
134                        )
135         :effect (and(not (full ?mat))
136                     (clean ?z)
137                     (increase (total-cost) 1)
138                 )
139     )
140
141     (:action clean-dangerous-zone
142         :parameters (?v - volunteer ?z - zone ?mat - radioactiveMaterial)
143         :precondition  (and(at-volunteer ?v ?z)
144                            (holding ?v ?mat)
145                            (full ?mat)
```

```
146                          )
147          :effect (and(not (full ?mat))
148                      (clean ?z)
149                      (exhausted ?v)
150                      (increase (total-cost) 1)
151              )
152      )
153
154      (:action get-medical-attention
155          :parameters (?v - volunteer ?z - zone)
156          :precondition   (and(at-volunteer ?v ?z)
157                              (reactor-entrance ?z)
158                              (not(exhausted ?v))
159                          )
160          :effect (and(not (at-volunteer ?v ?z))
161                      (health-care ?v)
162                      (not (in-reactor))
163                      (increase (total-cost) 1)
164              )
165      )
166
167      (:action take-to-hospital
168          :parameters (?v1 ?v2 - volunteer ?a - ambulance ?z - zone)
169          :precondition   (and(at-volunteer ?v1 ?z)
170                              (exhausted ?v1)
171                              (prezent ?a)
172                              (not(occupied ?a ?v2)
173                              )
174                          )
175          :effect (and(not (at-volunteer ?v1 ?z))
176                      (extra-health-care ?v1)
177                      (not (in-reactor))
178                      (not (prezent ?a))
179                      (occupied ?a ?v1)
180                      (increase (total-cost) 1)
181              )
182      )
183
184  )
```

Explanation: Fișierul domain conține secțiunile de denumire, de definire a listei predicatelor și variabilelor corespunzătoare, de definire a funcției necesare calculului costului și de definire a acțiunilor, cu predicatele, precondițiile și efectele corespunzătoare.

Pentru această problemă am definit 10 acțiuni

- call-volunteer -> Parametrul: voluntarul de chemat. Precondiții: este disponibil și nu a mai fost în reactor. Efecte: va fi out (pe teren), nu va mai fi disponibil, se va avea grijă ca următorii voluntari să fie aprecieați de acesta, va merge în reactor și se va crește costul total pentru rezolvarea problemei.

- call-ambulance -> Parametri: doua ambulanțe, una de chemat si una posibil prezenta si un voluntar ce e posibil luat de ambulanța ocupată.Preconditii:ambulanța prezentă este ocupată iar a doua nu este prezentă. Efecte: ambulanța chemată prezentă și creșterea costului

- localize-radioactive-material -> Parametri:voluntarul care va trebui să preia materialul, materialul anterior scos, cel ce urmează a fi scos, cantitatea scoasă înainte și cantitatea de scos. Precondiții:Voluntarul să fie pe poziție, materialul localizat, ordiunea cantităților hotărâtă, cantitatea de material de scos, precum și ordinea materialelor. Efecte:materialul scos nu va mai fi localizat, se va schima

cantitatea de cărat cu cea noua, materialul de scos va fi localizat, materialul 1 complet scos și costul mărit.

- enter-reactor
- take-radioactive-material
- take-out-radioactive-material
- walk
- clean-zone
- get-medical-attention
- take-to-hospital

1.2 Problem file

```
1   (define (problem chernobyl-operation-p)
2     (:domain chernobyl-operation)
3     (:objects
4       z0 z1 z2 z3 z4 z5 - zone
5       v0 v1 - volunteer
6       a0 a1 - ambulance
7       mat0 mat1 mat2 mat3 mat4 mat5 mat6 - radioactiveMaterial
8       zero one two three  - quantity
9     )
10
11    (:init
12      (available v0)
13      (available v1)
14      (prezent a0)
15      (capacity v0 three)
16      (capacity v1 three)
17      (localized mat0)
18      (next-material mat0 mat1)
19      (next-material mat1 mat2)
20      (next-material mat2 mat3)
21      (next-material mat3 mat4)
22      (next-material mat4 mat5)
23      (next-material mat5 mat6)
24      (reactor-entrance z0)
25      (connected z0 z1)
26      (connected z1 z0)
27      (connected z1 z2)
28      (connected z2 z1)
29      (connected z2 z3)
30      (connected z3 z2)
31      (connected z0 z4)
32      (connected z4 z0)
33      (connected z4 z5)
34      (connected z5 z4)
35      (next-quantity zero one)
36      (next-quantity one two)
37      (next-quantity two three)
38      (next-quantity three one)
39          (= (total-cost) 0)
40     )
```

```
41
42    (:goal
43      (and
44        (clean z5)
45        (extra-health-care v1)
46        (health-care v0)
47      )
48    )
49      (:metric minimize (total-cost))
50
51
52  )
```

Explanation: Fișierul problem listează domeniul, obiectele care pot fi utilizate ca variabile, o descriere a stării inițiale ,folosind predicatele listate în fișierul de domeniu și criteriile obiectivului ,folosind tot predicate.

Am definit 6 zone, doi voluntari, două ambulanțe 7 bucăți de material radioactiv și 4 cantități. Folosind unele predicate am creat legături între zone pentru a păstra structura de graf aciclic neorientat, dar am și stabilit ordinea materialelor și a cantităților, precum și disponibilitaea voluntarilor, ambulanțelor și localizarea unelor materiale sau voluntari.

Goalul este de a curăța zona cu numărul 5,de a duce voluntarul numărul 1 la spital pentru îngrijire de specialitate și de a acorda îngrijire voluntarului cu numărul 0.

1.3   Result

Rulând cu comanda ./fast-downward.py ./pb/DomainChernobyl.pddl ./pb/ProblemChernobyl.pddl –heuristic "h=ff()" –search "astar(h)" , am obținut următoarele:

```
1   INFO      Running translator.
2   INFO      translator stdin: None
3   INFO      translator time limit: None
4   INFO      translator memory limit: None
5   INFO      translator command line string: /usr/bin/python3 /home/strujanflorentina/Desktop/DIRNAME/builds
6   Parsing...
7   Parsing: [0.000s CPU, 0.002s wall-clock]
8   Normalizing task... [0.000s CPU, 0.000s wall-clock]
9   Instantiating...
10  Generating Datalog program... [0.000s CPU, 0.000s wall-clock]
11  Normalizing Datalog program...
12  Normalizing Datalog program: [0.010s CPU, 0.018s wall-clock]
13  Preparing model... [0.000s CPU, 0.001s wall-clock]
14  Generated 79 rules.
15  Computing model... [0.020s CPU, 0.014s wall-clock]
16  1139 relevant atoms
17  843 auxiliary atoms
18  1982 final queue length
19  3676 total queue pushes
20  Completing instantiation... [0.030s CPU, 0.045s wall-clock]
21  Instantiating: [0.060s CPU, 0.079s wall-clock]
22  Computing fact groups...
23  Finding invariants...
24  34 initial candidates
25  Finding invariants: [0.000s CPU, 0.008s wall-clock]
26  Checking invariant weight... [0.000s CPU, 0.000s wall-clock]
27  Instantiating groups... [0.000s CPU, 0.000s wall-clock]
28  Collecting mutex groups... [0.000s CPU, 0.000s wall-clock]
```

```
29  Choosing groups...
30  69 uncovered facts
31  Choosing groups: [0.000s CPU, 0.000s wall-clock]
32  Building translation key... [0.000s CPU, 0.000s wall-clock]
33  Computing fact groups: [0.000s CPU, 0.009s wall-clock]
34  Building STRIPS to SAS dictionary... [0.000s CPU, 0.000s wall-clock]
35  Building dictionary for full mutex groups... [0.000s CPU, 0.000s wall-clock]
36  Building mutex information...
37  Building mutex information: [0.000s CPU, 0.000s wall-clock]
38  Translating task...
39  Processing axioms...
40  Simplifying axioms... [0.000s CPU, 0.000s wall-clock]
41  Translator axioms removed by simplifying: 0
42  Computing negative axioms... [0.000s CPU, 0.000s wall-clock]
43  Processing axioms: [0.000s CPU, 0.001s wall-clock]
44  Translating task: [0.040s CPU, 0.064s wall-clock]
45  1370 effect conditions simplified
46  0 implied preconditions added
47  Detecting unreachable propositions...
48  0 operators removed
49  0 axioms removed
50  3 propositions removed
51  Detecting unreachable propositions: [0.020s CPU, 0.030s wall-clock]
52  Reordering and filtering variables...
53  67 of 74 variables necessary.
54  2 of 13 mutex groups necessary.
55  1166 of 1166 operators necessary.
56  0 of 0 axiom rules necessary.
57  Reordering and filtering variables: [0.010s CPU, 0.018s wall-clock]
58  Translator variables: 67
59  Translator derived variables: 0
60  Translator facts: 161
61  Translator goal facts: 3
62  Translator mutex groups: 2
63  Translator total mutex groups size: 18
64  Translator operators: 1166
65  Translator axioms: 0
66  Translator task size: 8480
67  Translator peak memory: 38816 KB
68  Writing output... [0.000s CPU, 0.008s wall-clock]
69  Done! [0.140s CPU, 0.214s wall-clock]
70  translate exit code: 0
71
72  INFO     Running search (release).
73  INFO       search stdin: output.sas
74  INFO       search time limit: None
75  INFO       search memory limit: None
76  INFO       search command line string: /home/strujanflorentina/Desktop/DIRNAME/builds/release/bin/downward
77  [t=0.000131042s, 9660 KB] reading input...
78  [t=0.00475612s, 10048 KB] done reading input!
79  [t=0.00638799s, 10440 KB] Simplifying 3343 unary operators... done! [2119 unary operators]
80  [t=0.00771041s, 10704 KB] time to simplify: 0.00141005s
81  [t=0.00785108s, 10704 KB] Initializing additive heuristic...
82  [t=0.00787179s, 10704 KB] Initializing FF heuristic...
```

```
 83  [t=0.00793483s, 10704 KB] Building successor generator...done!
 84  [t=0.00843728s, 10704 KB] peak memory difference for successor generator creation: 0 KB
 85  [t=0.00846423s, 10704 KB] time for successor generation creation: 0.000419561s
 86  [t=0.00852923s, 10704 KB] Variables: 67
 87  [t=0.00856945s, 10704 KB] FactPairs: 161
 88  [t=0.00861103s, 10704 KB] Bytes per state: 12
 89  [t=0.00876077s, 10704 KB] Conducting best first search with reopening closed nodes, (real) bound = 21474
 90  [t=0.00888935s, 10704 KB] New best heuristic value for ff: 12
 91  [t=0.00890806s, 10704 KB] g=0, 1 evaluated, 0 expanded
 92  [t=0.00892344s, 10704 KB] f = 12, 1 evaluated, 0 expanded
 93  [t=0.00894013s, 10704 KB] Initial heuristic value for ff: 12
 94  [t=0.00895464s, 10704 KB] pruning method: none
 95  [t=0.00899711s, 10704 KB] New best heuristic value for ff: 11
 96  [t=0.00901237s, 10704 KB] g=1, 2 evaluated, 1 expanded
 97  [t=0.00910555s, 10704 KB] New best heuristic value for ff: 9
 98  [t=0.0091326s, 10704 KB] g=2, 5 evaluated, 2 expanded
 99  [t=0.00916444s, 10704 KB] New best heuristic value for ff: 8
100  [t=0.00917956s, 10704 KB] g=3, 6 evaluated, 3 expanded
101  [t=0.00924208s, 10704 KB] New best heuristic value for ff: 7
102  [t=0.009282s, 10704 KB] g=4, 7 evaluated, 4 expanded
103  [t=0.00931264s, 10704 KB] New best heuristic value for ff: 6
104  [t=0.00932761s, 10704 KB] g=5, 8 evaluated, 5 expanded
105  [t=0.00937021s, 10704 KB] New best heuristic value for ff: 5
106  [t=0.00938506s, 10704 KB] g=6, 11 evaluated, 6 expanded
107  [t=0.00947944s, 10704 KB] New best heuristic value for ff: 4
108  [t=0.00949453s, 10704 KB] g=8, 21 evaluated, 9 expanded
109  [t=0.0100272s, 10704 KB] f = 13, 78 evaluated, 21 expanded
110  [t=0.0107281s, 10704 KB] New best heuristic value for ff: 3
111  [t=0.0107579s, 10704 KB] g=10, 167 evaluated, 39 expanded
112  [t=0.0109377s, 10704 KB] New best heuristic value for ff: 2
113  [t=0.0109572s, 10704 KB] g=10, 187 evaluated, 42 expanded
114  [t=0.0110503s, 10704 KB] New best heuristic value for ff: 1
115  [t=0.0110787s, 10704 KB] g=11, 194 evaluated, 43 expanded
116  [t=0.0111398s, 10704 KB] New best heuristic value for ff: 0
117  [t=0.0111586s, 10704 KB] g=12, 200 evaluated, 44 expanded
118  [t=0.0111978s, 10704 KB] Solution found!
119  [t=0.0112164s, 10704 KB] Actual search time: 0.00226103s
120  call-volunteer v0 (1)
121  enter-reactor v0 z0 (1)
122  get-medical-attention v0 z0 (1)
123  call-volunteer v1 (1)
124  localize-radioactive-material v1 mat0 mat1 two three (1)
125  localize-radioactive-material v1 mat1 mat2 one two (1)
126  localize-radioactive-material v1 mat2 mat3 three one (1)
127  enter-reactor v1 z0 (1)
128  walk v1 mat0 z0 z4 (1)
129  walk v1 mat1 z4 z5 (1)
130  clean-dangerous-zone v1 z5 mat2 (1)
131  take-to-hospital v1 v0 a0 z5 (1)
132  [t=0.0112344s, 10704 KB] Plan length: 12 step(s).
133  [t=0.0112344s, 10704 KB] Plan cost: 12
134  [t=0.0112344s, 10704 KB] Expanded 45 state(s).
135  [t=0.0112344s, 10704 KB] Reopened 0 state(s).
136  [t=0.0112344s, 10704 KB] Evaluated 203 state(s).
```

```
137  [t=0.0112344s, 10704 KB] Evaluations: 203
138  [t=0.0112344s, 10704 KB] Generated 257 state(s).
139  [t=0.0112344s, 10704 KB] Dead ends: 72 state(s).
140  [t=0.0112344s, 10704 KB] Expanded until last jump: 21 state(s).
141  [t=0.0112344s, 10704 KB] Reopened until last jump: 0 state(s).
142  [t=0.0112344s, 10704 KB] Evaluated until last jump: 78 state(s).
143  [t=0.0112344s, 10704 KB] Generated until last jump: 90 state(s).
144  [t=0.0112344s, 10704 KB] Number of registered states: 203
145  [t=0.0112344s, 10704 KB] Int hash set load factor: 203/256 = 0.792969
146  [t=0.0112344s, 10704 KB] Int hash set resizes: 8
147  [t=0.0112344s, 10704 KB] Search time: 0.00247582s
148  [t=0.0112344s, 10704 KB] Total time: 0.0112344s
149  Solution found.
150  Peak memory: 10704 KB
151  Remove intermediate file output.sas
152  search exit code: 0
```


Figure 1: Found Plan: Output

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