Laboratorium
Metody Sztucznej Inteligencji

ćwiczenie 7-8

Planowanie SI w języku PDDL

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Ćwiczenie 7

Zadanie 1)
Zamodelowanie i rozwiązanie przykładowych problemów znajdujących się w katalogu DOMAINS.

Problem: road-test
Domain: road-operatiors
Plik: travel.pddl

rozwiązanie:

```
Levels 1
  50 actions 52 propositions
 2
  66 actions 62 propositions
(((CROSS BULLDOZER A D) (CROSS CAR A D)) ((DRIVE CAR D G) (DRIVE BULLDOZER D G)))
```

statystyki:

```
Levels 1
Expanding graph...
Finding mutexes...
; cpu time (non-gc) 0.062500 sec user, 0.000000 sec system
; cpu time (gc)     0.015625 sec user, 0.000000 sec system
; cpu time (total)  0.078125 sec user, 0.000000 sec system
; real time   0.090000 sec (86.81%)
; space allocation:
;  672,686 cons cells, 6,385,488 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
; cpu time (non-gc) 0.281250 sec user, 0.015625 sec system
; cpu time (gc)     0.187500 sec user, 0.000000 sec system
; cpu time (total)  0.468750 sec user, 0.015625 sec system
; real time   0.480000 sec (100.9%)
; space allocation:
;  3,725,823 cons cells, 71,484,192 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
  50 actions 52 propositions
  8 action mutexes  16 proposition mutexes
Backward searching...
; cpu time (non-gc) 0.000000 sec user, 0.000000 sec system
; cpu time (gc)     0.000000 sec user, 0.000000 sec system
; cpu time (total)  0.000000 sec user, 0.000000 sec system
; real time   0.001000 sec (  0.0%)
; space allocation:
;  11,601 cons cells, 248,672 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
 2
Expanding graph...
Finding mutexes...
; cpu time (non-gc) 0.109375 sec user, 0.000000 sec system
; cpu time (gc)     0.015625 sec user, 0.000000 sec system
; cpu time (total)  0.125000 sec user, 0.000000 sec system
; real time   0.130000 sec (96.15%)
; space allocation:
;  970,929 cons cells, 9,280,912 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
; cpu time (non-gc) 0.625000 sec user, 0.000000 sec system
; cpu time (gc)     0.187500 sec user, 0.000000 sec system
; cpu time (total)  0.812500 sec user, 0.000000 sec system
; real time   0.828000 sec (98.13%)
; space allocation:
;  5,609,688 cons cells, 106,106,088 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
  66 actions 62 propositions
  76 action mutexes  24 proposition mutexes
Backward searching...
; cpu time (non-gc) 0.000000 sec user, 0.000000 sec system
; cpu time (gc)     0.000000 sec user, 0.000000 sec system
; cpu time (total)  0.000000 sec user, 0.000000 sec system
; real time   0.005000 sec (  0.0%)
; space allocation:
;  38,023 cons cells, 740,000 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
(((CROSS BULLDOZER A D) (CROSS CAR A D)) ((DRIVE CAR D G) (DRIVE BULLDOZER D G)))
```

Level	Time-expansion (s)	Time-bc (s)	Time-mutex (s)	Graph-size (akcje,propozycje)	Mutex-count (akcje, propozycje)
1	0.48	0.001	0.09	50-52	8-16
2	0.82	0.005	0.13	66-62	76-24
suma	1.3	0.006	0.22	--------	--------

Zadanie 2. Modyfikacja sytuacji początkowej i docelowej dla wybranej dziedziny i rozwiązanie zbioru problemów.

Pierwsza modyfikacja:

-Postanowiliśmy dodać dodatkową drogę od g do f, oraz zmieniliśmy sytuację początkową oraz docelową:

```
(define (problem road-test)
    (:domain road-operators)
  (:objects a d g f car bulldozer)
  (:init (vehicle car)(vehicle bulldozer)
        (place a)(place d)(place g)(place f)
        (at car a) (at bulldozer a)
        (road d g) (road g d)
        (road g f) (road f g)
        (bridge a d) (bridge d a))
  (:goal (and (at car f) (at bulldozer f))))
```

wyniki:

```
Levels 1
  78 actions 80 propositions
  2
  98 actions 92 propositions
  3
  114 actions 104 propositions
(((DRIVE CAR D G) (CROSS BULLDOZER A D)) ((DRIVE BULLDOZER D G) (DRIVE CAR G F)) ((DRIVE BULLDOZER G F)))
```

Statystyki:

```
Levels 1
Expanding graph...
Finding mutexes...
; cpu time (non-gc) 0.093750 sec user, 0.000000 sec system
; cpu time (gc)      0.062500 sec user, 0.000000 sec system
; cpu time (total)  0.156250 sec user, 0.000000 sec system
; real time  0.161000 sec (97.05%)
; space allocation:
;  1,581,003 cons cells, 14,689,936 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
; cpu time (non-gc) 0.640625 sec user, 0.015625 sec system
; cpu time (gc)      0.437500 sec user, 0.000000 sec system
; cpu time (total)  1.078125 sec user, 0.015625 sec system
; real time  1.107000 sec ( 98.8%)
; space allocation:
;  8,543,759 cons cells, 164,299,664 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
  78 actions 80 propositions
  14 action mutexes  20 proposition mutexes
Backward searching...
; cpu time (non-gc) 0.000000 sec user, 0.000000 sec system
; cpu time (gc)      0.000000 sec user, 0.000000 sec system
; cpu time (total)  0.000000 sec user, 0.000000 sec system
; real time  0.001000 sec (  0.0%)
; space allocation:
;  17,005 cons cells, 367,168 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
  2
Expanding graph...
Finding mutexes...
; cpu time (non-gc) 0.140625 sec user, 0.000000 sec system
; cpu time (gc)      0.078125 sec user, 0.000000 sec system
; cpu time (total)  0.218750 sec user, 0.000000 sec system
; real time  0.222000 sec (98.54%)
; space allocation:
;  2,113,341 cons cells, 19,737,440 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
; cpu time (non-gc) 1.140625 sec user, 0.015625 sec system
; cpu time (gc)      0.484375 sec user, 0.000000 sec system
; cpu time (total)  1.625000 sec user, 0.015625 sec system
; real time  1.658000 sec (98.95%)
; space allocation:
;  12,956,028 cons cells, 248,749,304 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
  98 actions 92 propositions
  120 action mutexes  32 proposition mutexes
Backward searching...
; cpu time (non-gc) 0.000000 sec user, 0.000000 sec system
; cpu time (gc)      0.000000 sec user, 0.000000 sec system
; cpu time (total)  0.000000 sec user, 0.000000 sec system
; real time  0.005000 sec (  0.0%)
; space allocation:
;  38,774 cons cells, 838,888 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
```

```
; ...  ...  ...  .......   ..  ..  .. .....
 3
Expanding graph...
Finding mutexes...
; cpu time (non-gc) 0.250000 sec user, 0.000000 sec system
; cpu time (gc)     0.078125 sec user, 0.000000 sec system
; cpu time (total)  0.328125 sec user, 0.000000 sec system
; real time  0.324000 sec (101.3%)
; space allocation:
;  2,708,939 cons cells, 25,277,784 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
; cpu time (non-gc) 1.343750 sec user, 0.000000 sec system
; cpu time (gc)     0.843750 sec user, 0.000000 sec system
; cpu time (total)  2.187500 sec user, 0.000000 sec system
; real time  2.191000 sec (99.84%)
; space allocation:
;  16,376,474 cons cells, 307,819,592 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
   114 actions 104 propositions
   204 action mutexes  40 proposition mutexes
Backward searching...
; cpu time (non-gc) 0.000000 sec user, 0.000000 sec system
; cpu time (gc)     0.015625 sec user, 0.000000 sec system
; cpu time (total)  0.015625 sec user, 0.000000 sec system
; real time  0.009000 sec (173.6%)
; space allocation:
;  63,618 cons cells, 1,231,040 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
(((DRIVE CAR D G) (CROSS BULLDOZER A D)) ((DRIVE BULLDOZER D G) (DRIVE CAR G F)) ((DRIVE BULLDOZER G F)))
```

Level	Time-expansion (s)	Time-bc (s)	Time-mutex (s)	Graph-size (akcje,propozycje)	Mutex-count (akcje, propozycje)
1	1.107	0.001	0.161	78-80	14-20
2	1.658	0.005	0.222	98-92	120-32
3	2.191	0.009	0.324	114-104	204-40
suma	4.956	0.015	0.707	-----------	-----------

Druga modyfikacja:

Postanowiliśmy dodać do domenu road-operators nową drogę do przebycia (tunel) którą można przebyć nową akcją (drive-through). Zmieniliśmy również sytuacje początkową i docelową w problemie. Miejscem docelowym jest miejsce 'i' do którego można się dostać poprzez tunel z miejsca 'f'.

```
(define (domain road-operators)
 (:requirements :strips)
 (:predicates (at ?v ?l)
 (road ?l1 ?l2)
 (bridge ?l1 ?l2)
 (tunel ?l1 ?l2)
 (place ?l)
 (vehicle ?v))
 (:action drive
 :parameters (?vehicle ?location1 ?location2)
 :precondition (and (at ?vehicle ?location1)
 (road ?location1 ?location2))
 :effect
 (and (at ?vehicle ?location2)
 (not (at ?vehicle ?location1))))
 (:action cross
 :parameters (?vehicle ?location1 ?location2)
 :precondition (and (at ?vehicle ?location1)
 (bridge ?location1 ?location2))
 :effect
 (and (at ?vehicle ?location2)
 (not (at ?vehicle ?location1))))
 (:action drive-through
 :parameters (?vehicle ?location1 ?location2)
 :precondition (and (at ?vehicle ?location1)
 (tunel ?location1 ?location2))
 :effect
 (and (at ?vehicle ?location2)
 (not (at ?vehicle ?location1)))))
```

```
(define (problem road-test-1)
 (:domain road-operators)
 (:objects a d g f i car bulldozer)
 (:init (vehicle car)(vehicle bulldozer)
 (place a)(place d)(place g)(place f)
 (at car d) (at bulldozer a)
 (road d g) (road g d)
 (road g f) (road f g)
 (bridge a d) (bridge d a)
 (tunel f i) (tunel i f))
 (:goal (and (at car i) (at bulldozer i))))
```

wyniki:

```
Levels 1
  112 actions 114 propositions
 2
  141 actions 135 propositions
 3
  166 actions 156 propositions
 4
  191 actions 177 propositions
(((CROSS BULLDOZER A D) (DRIVE CAR D G)) ((DRIVE CAR G F) (DRIVE BULLDOZER D G)) ((DRIVE BULLDOZER G F) (DRIVE-THROUGH CAR F I))
 ((DRIVE-THROUGH BULLDOZER F I)))
```

Statystyki:

```
Levels 1
Expanding graph...
Finding mutexes...
; cpu time (non-gc) 0.218750 sec user, 0.000000 sec system
; cpu time (gc)     0.125000 sec user, 0.000000 sec system
; cpu time (total)  0.343750 sec user, 0.000000 sec system
; real time  0.340000 sec (101.1%)
; space allocation:
;  3,195,150 cons cells, 29,280,064 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
; cpu time (non-gc) 2.015625 sec user, 0.000000 sec system
; cpu time (gc)     1.250000 sec user, 0.000000 sec system
; cpu time (total)  3.265625 sec user, 0.000000 sec system
; real time  3.283000 sec (99.47%)
; space allocation:
;  25,385,164 cons cells, 509,240,944 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
  112 actions 114 propositions
  14 action mutexes  20 proposition mutexes
Backward searching...
; cpu time (non-gc) 0.000000 sec user, 0.000000 sec system
; cpu time (gc)     0.000000 sec user, 0.000000 sec system
; cpu time (total)  0.000000 sec user, 0.000000 sec system
; real time  0.004000 sec (  0.0%)
; space allocation:
;  23,329 cons cells, 505,712 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
 2
Expanding graph...
Finding mutexes...
; cpu time (non-gc) 0.328125 sec user, 0.000000 sec system
; cpu time (gc)     0.171875 sec user, 0.000000 sec system
; cpu time (total)  0.500000 sec user, 0.000000 sec system
; real time  0.493000 sec (101.4%)
; space allocation:
;  4,500,303 cons cells, 41,256,176 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
; cpu time (non-gc) 2.921875 sec user, 0.000000 sec system
; cpu time (gc)     1.921875 sec user, 0.000000 sec system
; cpu time (total)  4.843750 sec user, 0.000000 sec system
; real time  4.895000 sec (98.95%)
; space allocation:
;  38,364,549 cons cells, 761,744,968 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
  141 actions 135 propositions
  120 action mutexes  32 proposition mutexes
Backward searching...
; cpu time (non-gc) 0.000000 sec user, 0.000000 sec system
; cpu time (gc)     0.000000 sec user, 0.000000 sec system
; cpu time (total)  0.000000 sec user, 0.000000 sec system
; real time  0.004000 sec (  0.0%)
; space allocation:
;  27,529 cons cells, 597,944 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
```

```
    3
Expanding graph...
Finding mutexes...
; cpu time (non-gc) 0.562500 sec user, 0.000000 sec system
; cpu time (gc)     0.078125 sec user, 0.000000 sec system
; cpu time (total)  0.640625 sec user, 0.000000 sec system
; real time  0.648000 sec (98.86%)
; space allocation:
;  6,018,520 cons cells, 55,097,872 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
; cpu time (non-gc) 3.937500 sec user, 0.031250 sec system
; cpu time (gc)     2.140625 sec user, 0.000000 sec system
; cpu time (total)  6.078125 sec user, 0.031250 sec system
; real time  6.121000 sec (99.81%)
; space allocation:
;  48,643,295 cons cells, 947,339,744 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
  166 actions 156 propositions
  228 action mutexes  50 proposition mutexes
Backward searching...
; cpu time (non-gc) 0.015625 sec user, 0.000000 sec system
; cpu time (gc)     0.000000 sec user, 0.000000 sec system
; cpu time (total)  0.015625 sec user, 0.000000 sec system
; real time  0.007000 sec (223.2%)
; space allocation:
;  63,193 cons cells, 1,373,752 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
    4
Expanding graph...
Finding mutexes...
; cpu time (non-gc) 0.578125 sec user, 0.000000 sec system
; cpu time (gc)     0.250000 sec user, 0.000000 sec system
; cpu time (total)  0.828125 sec user, 0.000000 sec system
; real time  0.819000 sec (101.1%)
; space allocation:
;  7,753,438 cons cells, 71,114,088 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
; cpu time (non-gc) 4.718750 sec user, 0.015625 sec system
; cpu time (gc)     2.546875 sec user, 0.000000 sec system
; cpu time (total)  7.265625 sec user, 0.015625 sec system
; real time  7.309000 sec (99.62%)
; space allocation:
;  58,661,159 cons cells, 1,116,671,120 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
  191 actions 177 propositions
  344 action mutexes  60 proposition mutexes
Backward searching...
; cpu time (non-gc) 0.000000 sec user, 0.000000 sec system
; cpu time (gc)     0.000000 sec user, 0.000000 sec system
; cpu time (total)  0.000000 sec user, 0.000000 sec system
; real time  0.013000 sec (  0.0%)
; space allocation:
;  105,659 cons cells, 2,060,736 other bytes, 0 static bytes
; Page Faults: major: 0 (gc: 0), minor: 0 (gc: 0)
```

Level	Time-expansion (s)	Time-bc (s)	Time-mutex (s)	Graph-size (akcje,propozycje)	Mutex-count (akcje, propozycje)
1	3.283	0.004	0.34	112-114	14-20
2	4.895	0.004	0.493	141-135	120-32
3	6.121	0.007	0.648	166-156	228-50
4	7.309	0.013	0.819	191-177	344-60
suma	21.608	0.028	2.3	----------	-----------

Wnioski:

Analizując powyższe wyniki możemy zauważyć, że wraz ze wzrostem liczby poziomów rosną pozostałe statystyki. Nie tylko wzrastają czasy (time-expansion, time-bc, time mutex), wzrastają również liczby akcji i propozycji dla każdego level'u algorytmu.

Ćwiczenie 8

Zadanie 1)
Zamodelowanie problemu w którym można wykorzystać dodatkową informację pochodzącą z sensorów, co prowadzi do poszukiwania planu warunkowego.

BEZ SENSORA:

Kod przed wprowadzeniem modyfikacji (3 paczki do sprawdzenia):

```
(define (problem bt-3p);
        (:domain bt)
        (:objects b p1 p2 p3)
        (:init (package p1) (package p2) (package p3)
                (bomb b)
                        (oneof (in p1 b) (in p2 b)(in p3 b)))
        (:goal (defused b)))
```

Wynik przed wprowadzeniem modyfikacji:

```
3 contexts
Contexts:
--- 1 ---
    (OBJECT B)
    (OBJECT P1)
    (OBJECT P2)
    (OBJECT P3)
    (IN P3 B)
    (NOT (IN P1 B))
    (NOT (IN P2 B))
    (BOMB B)
    (PACKAGE P3)
    (PACKAGE P2)
    (PACKAGE P1)
--- 2 ---
    (OBJECT B)
    (OBJECT P1)
    (OBJECT P2)
    (OBJECT P3)
    (NOT (IN P3 B))
    (IN P2 B)
    (NOT (IN P1 B))
    (BOMB B)
    (PACKAGE P3)
    (PACKAGE P2)
    (PACKAGE P1)
--- 3 ---
    (OBJECT B)
    (OBJECT P1)
    (OBJECT P2)
    (OBJECT P3)
    (NOT (IN P3 B))
    (NOT (IN P2 B))
    (IN P1 B)
    (BOMB B)
    (PACKAGE P3)
    (PACKAGE P2)
    (PACKAGE P1)

Levels
***** 1 *****
Actions: 9  Propositions: 1
((((DOMAINS::DUNK DOMAINS::P1)) ((DOMAINS::DUNK DOMAINS::P2)) ((DOMAINS::DUNK DOMAINS::P3))))
```

Modyfikacja – zwiększenie liczby paczek do 6.

```
(define (problem bt-6p);
        (:domain bt)
        (:objects b p1 p2 p3 p4 p5 p6)
        (:init (package p1) (package p2) (package p3) (package p4) (package p5) (package p6)
                (bomb b)
                        (oneof (in p1 b) (in p2 b) (in p3 b) (in p4 b) (in p5 b) (in p6 b) ))
        (:goal (defused b)))
```

```
6 contexts
Contexts:
--- 1 ---
    (OBJECT B)
    (OBJECT P1)
    (OBJECT P2)
    (OBJECT P3)
    (OBJECT P4)
    (OBJECT P5)
    (OBJECT P6)
    (IN P6 B)
    (NOT (IN P1 B))
    (NOT (IN P2 B))
    (NOT (IN P3 B))
    (NOT (IN P4 B))
    (NOT (IN P5 B))
    (BOMB B)
    (PACKAGE P6)
    (PACKAGE P5)
    (PACKAGE P4)
    (PACKAGE P3)
    (PACKAGE P2)
    (PACKAGE P1)
--- 2 ---
    (OBJECT B)
    (OBJECT P1)
    (OBJECT P2)
    (OBJECT P3)
    (OBJECT P4)
    (OBJECT P5)
    (OBJECT P6)
    (NOT (IN P6 B))
    (IN P5 B)
    (NOT (IN P1 B))
    (NOT (IN P2 B))
    (NOT (IN P3 B))
    (NOT (IN P4 B))
    (BOMB B)
    (PACKAGE P6)
    (PACKAGE P5)
    (PACKAGE P4)
    (PACKAGE P3)
    (PACKAGE P2)
    (PACKAGE P1)
--- 3 ---
    (OBJECT B)
    (OBJECT P1)
    (OBJECT P2)
    (OBJECT P3)
    (OBJECT P4)
    (OBJECT P5)
    (OBJECT P6)
    (NOT (IN P6 B))
    (NOT (IN P5 B))
    (IN P4 B)
    (NOT (IN P1 B))
    (NOT (IN P2 B))
    (NOT (IN P3 B))
    (BOMB B)
    (PACKAGE P6)
    (PACKAGE P5)
    (PACKAGE P4)
    (PACKAGE P3)
    (PACKAGE P2)
    (PACKAGE P1)

--- 4 ---
    (OBJECT B)
    (OBJECT P1)
    (OBJECT P2)
    (OBJECT P3)
    (OBJECT P4)
    (OBJECT P5)
    (OBJECT P6)
    (NOT (IN P6 B))
    (NOT (IN P5 B))
    (NOT (IN P4 B))
    (IN P3 B)
    (NOT (IN P1 B))
    (NOT (IN P2 B))
    (BOMB B)
    (PACKAGE P6)
    (PACKAGE P5)
    (PACKAGE P4)
    (PACKAGE P3)
    (PACKAGE P2)
    (PACKAGE P1)
--- 5 ---
    (OBJECT B)
    (OBJECT P1)
    (OBJECT P2)
    (OBJECT P3)
    (OBJECT P4)
    (OBJECT P5)
    (OBJECT P6)
    (NOT (IN P6 B))
    (NOT (IN P5 B))
    (NOT (IN P4 B))
    (NOT (IN P3 B))
    (IN P2 B)
    (NOT (IN P1 B))
    (BOMB B)
    (PACKAGE P6)
    (PACKAGE P5)
    (PACKAGE P4)
    (PACKAGE P3)
    (PACKAGE P2)
    (PACKAGE P1)
--- 6 ---
    (OBJECT B)
    (OBJECT P1)
    (OBJECT P2)
    (OBJECT P3)
    (OBJECT P4)
    (OBJECT P5)
    (OBJECT P6)
    (NOT (IN P6 B))
    (NOT (IN P5 B))
    (NOT (IN P4 B))
    (NOT (IN P3 B))
    (NOT (IN P2 B))
    (IN P1 B)
    (BOMB B)
    (PACKAGE P6)
    (PACKAGE P5)
    (PACKAGE P4)
    (PACKAGE P3)
    (PACKAGE P2)
    (PACKAGE P1)


    Levels
    ***** 1 *****
    Actions:  36  Propositions:  1
    (((((DOMAINS::DUNK DOMAINS::P1)) ((DOMAINS::DUNK DOMAINS::P2)) ((DOMAINS::DUNK DOMAINS::P3)) ((DOMAINS::DUNK DOMAINS::P4))
      ((DOMAINS::DUNK DOMAINS::P5)) ((DOMAINS::DUNK DOMAINS::P6))))
```

Z sensorem:

Kod programu:

```
(define (problem bt-2-3paczki-1toaleta) (:domain bt-sensory-2SA)
        (:objects pkg1 pkg2 pkg3 toilet1)
        (:init (not (clogged toilet1))
                (toilet toilet1)
                (armed)|
                (oneof (in pkg1) (in pkg2) (in pkg3))
                (iff (in pkg1) (metal pkg1))
                (iff (in pkg2) (metal pkg2))
                (iff (in pkg3) (metal pkg3))

                (iff (in pkg1) (odor-of-explosives pkg2))
                (iff (in pkg2) (odor-of-explosives pkg2))
                (iff (in pkg3) (odor-of-explosives pkg3))
                )
                (:goal (not (armed))))
```

Rozwiązanie problemu:

```
1 context
Contexts:
--- 1 ---
     (OBJECT PKG1)
     (OBJECT PKG2)
     (OBJECT PKG3)
     (OBJECT TOILET1)
     (ODOR-OF-EXPLOSIVES PKG3)
     (NOT (ODOR-OF-EXPLOSIVES PKG2))
     (METAL PKG3)
     (NOT (METAL PKG2))
     (NOT (METAL PKG1))
     (IN PKG3)
     (NOT (IN PKG1))
     (NOT (IN PKG2))
     (ARMED)
     (TOILET TOILET1)
     (NOT (CLOGGED TOILET1))

Levels
***** 1 *****
Actions:  10  Propositions:  4
(((((DOMAINS::DUNK DOMAINS::PKG3 DOMAINS::TOILET1))))
```

Pierwsza modyfikacja problemu – dodanie dodatkowej paczki oraz toalety
Kod problemu:

```
(define (problem bt-2-4paczki-2toalety) (:domain bt-sensory-2SA)
        (:objects pkg1 pkg2 pkg3 pkg4 toilet1 toilet2)
        (:init (not (clogged toilet1))
                (not (clogged toilet2))
                (toilet toilet1)
                (toilet toilet2)
                (armed)
                (oneof (in pkg1) (in pkg2) (in pkg3) (in pkg4))
                (iff (in pkg1) (metal pkg1))
                (iff (in pkg2) (metal pkg2))
                (iff (in pkg3) (metal pkg3))
                (iff (in pkg3) (metal pkg4))

                (iff (in pkg1) (odor-of-explosives pkg2))
                (iff (in pkg2) (odor-of-explosives pkg2))
                (iff (in pkg3) (odor-of-explosives pkg3))
                (iff (in pkg3) (odor-of-explosives pkg4))
                )
                (:goal (not (armed))))
```

rozwiązanie problemu:

```
2 contexts
Contexts:
--- 1 ---
    (OBJECT PKG1)
    (OBJECT PKG2)
    (OBJECT PKG3)
    (OBJECT PKG4)
    (OBJECT TOILET1)
    (OBJECT TOILET2)
    (NOT (ODOR-OF-EXPLOSIVES PKG4))
    (NOT (ODOR-OF-EXPLOSIVES PKG3))
    (NOT (ODOR-OF-EXPLOSIVES PKG2))
    (NOT (METAL PKG4))
    (NOT (METAL PKG3))
    (NOT (METAL PKG2))
    (NOT (METAL PKG1))
    (IN PKG4)
    (NOT (IN PKG1))
    (NOT (IN PKG2))
    (NOT (IN PKG3))
    (ARMED)
    (TOILET TOILET2)
    (TOILET TOILET1)
    (NOT (CLOGGED TOILET2))
    (NOT (CLOGGED TOILET1))
--- 2 ---
    (OBJECT PKG1)
    (OBJECT PKG2)
    (OBJECT PKG3)
    (OBJECT PKG4)
    (OBJECT TOILET1)
    (OBJECT TOILET2)
    (ODOR-OF-EXPLOSIVES PKG4)
    (ODOR-OF-EXPLOSIVES PKG3)
    (NOT (ODOR-OF-EXPLOSIVES PKG2))
    (METAL PKG4)
    (METAL PKG3)
    (NOT (METAL PKG2))
    (NOT (METAL PKG1))
    (NOT (IN PKG4))
    (IN PKG3)
    (NOT (IN PKG1))
    (NOT (IN PKG2))
    (ARMED)
    (TOILET TOILET2)
    (TOILET TOILET1)
    (NOT (CLOGGED TOILET2))
    (NOT (CLOGGED TOILET1))

Levels
***** 1 *****
Actions:  36  Propositions:  8
(((((DOMAINS::DUNK DOMAINS::PKG3 DOMAINS::TOILET1)) ((DOMAINS::DUNK DOMAINS::PKG4 DOMAINS::TOILET2))))
```

Druga modyfikacja problemu – zmiana celu
kod problemu:

```
(define (problem bt-2-4paczki-2toalety) (:domain bt-sensory-2SA)
        (:objects pkg1 pkg2 pkg3 pkg4 toilet1 toilet2)
        (:init (not (clogged toilet1))
               (not (clogged toilet2))
               (toilet toilet1)
               (toilet toilet2)
               (armed)
               (oneof (in pkg1) (in pkg2) (in pkg3) (in pkg4))
               (iff (in pkg1) (metal pkg1))
               (iff (in pkg2) (metal pkg2))
               (iff (in pkg3) (metal pkg3))
               (iff (in pkg3) (metal pkg4))

               (iff (in pkg1) (odor-of-explosives pkg2))
               (iff (in pkg2) (odor-of-explosives pkg2))
               (iff (in pkg3) (odor-of-explosives pkg3))
               (iff (in pkg3) (odor-of-explosives pkg4))
               )
               (:goal (and (not (armed)) (not (clogged toilet1)))))))
```

Rozwiązanie problemu:

```
2 contexts
Contexts:
--- 1 ---
    (OBJECT PKG1)
    (OBJECT PKG2)
    (OBJECT PKG3)
    (OBJECT PKG4)
    (OBJECT TOILET1)
    (OBJECT TOILET2)
    (NOT (ODOR-OF-EXPLOSIVES PKG4))
    (NOT (ODOR-OF-EXPLOSIVES PKG3))
    (NOT (ODOR-OF-EXPLOSIVES PKG2))
    (NOT (METAL PKG4))
    (NOT (METAL PKG3))
    (NOT (METAL PKG2))
    (NOT (METAL PKG1))
    (IN PKG4)
    (NOT (IN PKG1))
    (NOT (IN PKG2))
    (NOT (IN PKG3))
    (ARMED)
    (TOILET TOILET2)
    (TOILET TOILET1)
    (NOT (CLOGGED TOILET2))
    (NOT (CLOGGED TOILET1))
--- 2 ---
    (OBJECT PKG1)
    (OBJECT PKG2)
    (OBJECT PKG3)
    (OBJECT PKG4)
    (OBJECT TOILET1)
    (OBJECT TOILET2)
    (ODOR-OF-EXPLOSIVES PKG4)
    (ODOR-OF-EXPLOSIVES PKG3)
    (NOT (ODOR-OF-EXPLOSIVES PKG2))
    (METAL PKG4)
    (METAL PKG3)
    (NOT (METAL PKG2))
    (NOT (METAL PKG1))
    (NOT (IN PKG4))
    (IN PKG3)
    (NOT (IN PKG1))
    (NOT (IN PKG2))
    (ARMED)
    (TOILET TOILET2)
    (TOILET TOILET1)
    (NOT (CLOGGED TOILET2))
    (NOT (CLOGGED TOILET1))

Levels
***** 1 *****
Actions: 36  Propositions: 8
***** 2 *****
Actions: 68  Propositions: 8
((((DOMAINS::DETECT-METAL DOMAINS::PKG3))) (((DOMAINS::DUNK DOMAINS::PKG3 DOMAINS::TOILET2) 1) ((DOMAINS::DUNK DOMAINS::PKG4 DOMAINS::TOILET2) 2)))
```

Trzecia modyfikacja – kolejna zmiana celu

```
(define (problem bt-2-4paczki-2toalety) (:domain bt-sensory-2SA)
        (:objects pkg1 pkg2 pkg3 pkg4 toilet1 toilet2)
        (:init (not (clogged toilet1))
               (not (clogged toilet2))
               (toilet toilet1)
               (toilet toilet2)
               (armed)
               (oneof (in pkg1) (in pkg2) (in pkg3) (in pkg4))
               (iff (in pkg1) (metal pkg1))
               (iff (in pkg2) (metal pkg2))
               (iff (in pkg3) (metal pkg3))
               (iff (in pkg3) (metal pkg4))

               (iff (in pkg1) (odor-of-explosives pkg2))
               (iff (in pkg2) (odor-of-explosives pkg2))
               (iff (in pkg3) (odor-of-explosives pkg3))
               (iff (in pkg3) (odor-of-explosives pkg4))
               )
        (:goal (and (not (armed)) (not (clogged toilet1))(not (clogged toilet2)))))
```

Rozwiązanie:

```
Contexts:
--- 1 ---
     (OBJECT PKG1)
     (OBJECT PKG2)
     (OBJECT PKG3)
     (OBJECT PKG4)
     (OBJECT TOILET1)
     (OBJECT TOILET2)
     (NOT (ODOR-OF-EXPLOSIVES PKG4))
     (NOT (ODOR-OF-EXPLOSIVES PKG3))
     (NOT (ODOR-OF-EXPLOSIVES PKG2))
     (NOT (METAL PKG4))
     (NOT (METAL PKG3))
     (NOT (METAL PKG2))
     (NOT (METAL PKG1))
     (IN PKG4)
     (NOT (IN PKG1))
     (NOT (IN PKG2))
     (NOT (IN PKG3))
     (ARMED)
     (TOILET TOILET2)
     (TOILET TOILET1)
     (NOT (CLOGGED TOILET2))
     (NOT (CLOGGED TOILET1))
--- 2 ---
     (OBJECT PKG1)
     (OBJECT PKG2)
     (OBJECT PKG3)
     (OBJECT PKG4)
     (OBJECT TOILET1)
     (OBJECT TOILET2)
     (ODOR-OF-EXPLOSIVES PKG4)
     (ODOR-OF-EXPLOSIVES PKG3)
     (NOT (ODOR-OF-EXPLOSIVES PKG2))
     (METAL PKG4)
     (METAL PKG3)
     (NOT (METAL PKG2))
     (NOT (METAL PKG1))
     (NOT (IN PKG4))
     (IN PKG3)
     (NOT (IN PKG1))
     (NOT (IN PKG2))
     (ARMED)
     (TOILET TOILET2)
     (TOILET TOILET1)
     (NOT (CLOGGED TOILET2))
     (NOT (CLOGGED TOILET1))

Levels
***** 1 *****
Actions:  36  Propositions:  8
***** 2 *****
Actions:  68  Propositions:  8
***** 3 *****
Actions:  68  Propositions:  8
***** 4 *****
Actions:  68  Propositions:  8
***** 5 *****
Actions:  68  Propositions:  8
***** 6 *****
Actions:  68  Propositions:  8
***** 7 *****
Actions:  68  Propositions:  8
***** 8 *****
Actions:  68  Propositions:  8
***** 9 *****
Actions:  68  Propositions:  8
***** 10 *****
Actions:  68  Propositions:  8
```

Wnioski:

Obserwując uzyskane wyniki możemy wywnioskować, że wraz ze wzrostem ilości paczek, oraz toalet wzrasta liczba akcji i propozycji. Dla pierwszego problemu, gdzie występowały 3 paczki i 1 toaleta otrzymano 10 akcji, a dla problemu gdzie występowały 4 paczki i 2 toalety otrzymano 36 akcji. Zastosowano sensory – wykrywacz metalu oraz psa. Kolejaną modyfikacją było zmienienie celu poprzez dodanie warunku 'not clogged toilet 1'. Poskutkowało to wzrostem poziomów do 2, gdzie liczba akcji wynosiła 68. Ostatnią modyfikacją było dodanie jeszcze kolejnego warunku tym razem dotyczącego toalety drugiej - 'not clogged toilet 2'. Dla tego problemu nie uzyskano rozwiązania.