Linköping University

TDDC17 Artificial Intelligence :

Lab 4 : Introduction to planning

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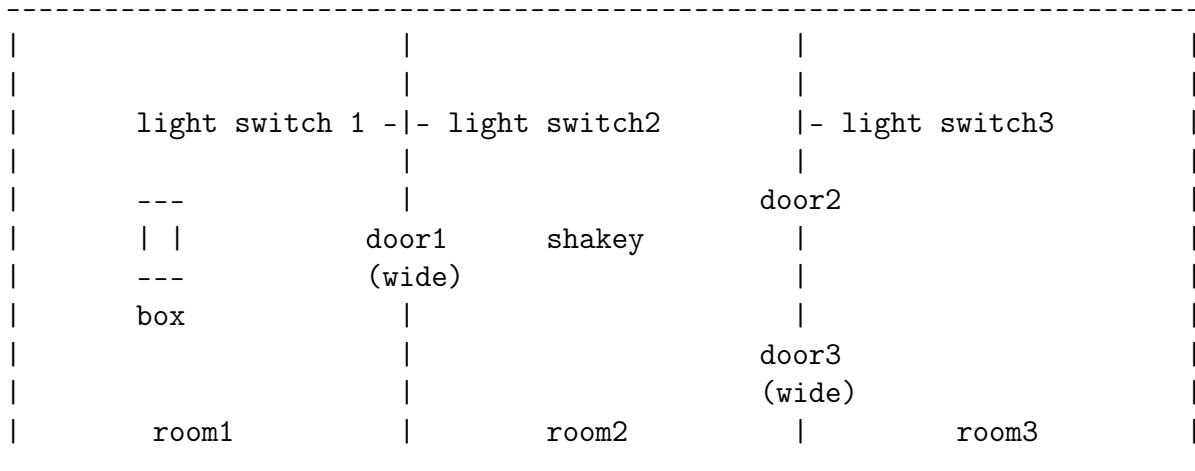# Task 1 : Writing Domain and Problem

The aim of this fourth lab is to learn how to model a problem that can be solved with automatic solvers called planners, using a formal language : PDDL.

Different domains alternatives are suggested. I have chosen to implement the AI classic Shakey's World.

Shakey is a robot with two grippers that is moving in a set of rooms, connected by doors. Each room contains a lightswitch which can be on or off but may also contain big boxes or smaller objects.

The lab page defines the following constraints :
— Shakey can carry small objects, but only two at a time because he has only two grippers.
— For Shakey to be able to find a small object in a room, the light must be on in that room.
— Shakey can not carry boxes, but can push them around. Boxes can only be pushed through wide doors, not narrow ones.
— To switch the light in a room on or off Shakey must climb onto a box that is positioned below the switch (otherwise he can not reach the switch). This may in turn require moving the box into position, possibly from another room.

```
-----------------------------------------------------------------------
|               |                 |                 |                 |
|               |                 |                 |                 |
|      light switch 1 -|- light switch2       |- light switch3        |
|               |                 |                 |                 |
|      ---       |                     door2       |                 |
|      | |        door1       shakey       |                 |
|      ---       (wide)                   |                 |
|      box        |                      |                 |
|               |                     door3           |                 |
|               |                     (wide)          |                 |
|      room1     |         room2      |         room3     |
-----------------------------------------------------------------------
```

SRI Shakey's World

The following actions have been implemented in the domain definition file : move, push, climb, descend, turnon and pickup and drop.

A few assumptions have been made :
— Doors are either opened wide or narrow, it is not possible to change the opening.
— Shakey pushing a box from a room to another imply Shakey also being in the destination room.
— When Shakey is on a box, he can only turn a light on, he has to reach the ground before being able to move.

Please refer to the code and comments for more details regarding the implementation.

Testing the domain with a simple problem

The example below is very simple problem just to test the domain. Shakey is in room-1 and must bring the ball from room-1 to room-3 and then go back to room-1. A climbable box is in room-1.

The goal is defined as follow :

```
(:goal (and(in ball room-3) (in shakey room-1 )))
```

Using *vhpop* planner on this simple problem we get the following solution :


```
1:(climb shakey box room-1)
2:(turnon shakey lswitch-1 room-1)
3:(descend shakey)
4:(pickup shakey ball room-1 lswitch-1 leftarm)
5:(move shakey room-1 room-2 door-1)
6:(move shakey room-2 room-3 door-2)
7:(drop shakey ball room-3 leftarm)
8:(move shakey room-3 room-2 door-2)
9:(move shakey room-2 room-1 door-1)
Time: 3227
```

FIGURE 1 – Actions sequence using vhpop

Task 2 : Problems and performance comparison

In this part we are going to test and compare the different planners on a range of problems with increasing difficulty.
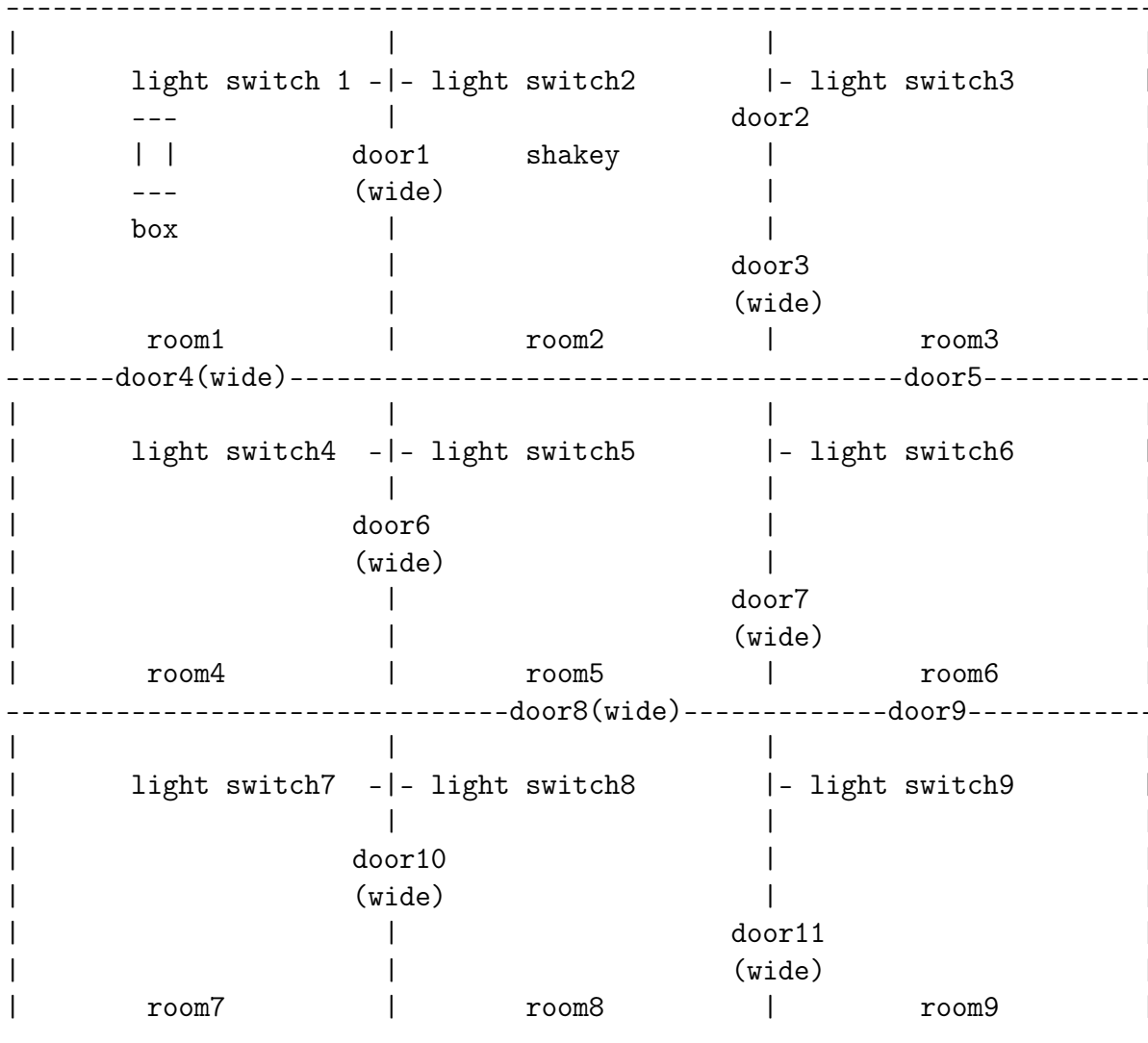
Identifying parameters

In order to create this range of problem, we first have to identify the parameters that can be modified to scale up the difficulty.

— World dimensions : the default domain (see page 1) is composed of only three rooms. If we add more rooms or change the disposition to a grid of (n,m) rooms, the complexity increases rapidly.
— The number of objects : The difficulty increases if we add more balls to carry to different places. If we limit the number of climbable boxes to 1, forcing Shakey to move to the box, then push it to the switch location, and so on...
— The initial state : If the initial state contains already achieved goal conditions, the complexity is reduced.

We are going to increase the number of balls and the world dimension.

The world dimension will be enlarged into a 3 by 3 room grid in the lasts problems.

```
------------------------------------------------------------------------
|                      |                    |                          |
|      light switch 1 -|- light switch2     |- light switch3           |
|      ---             |                  door2                        |
|      | |           door1       shakey     |                          |
|      ---           (wide)                 |                          |
|      box             |                    |                          |
|                      |                  door3                        |
|                      |                  (wide)                       |
|       room1          |        room2       |        room3             |
-------door4(wide)---------------------------------------door5----------
|                      |                    |                          |
|      light switch4  -|- light switch5     |- light switch6           |
|                      |                    |                          |
|                    door6                  |                          |
|                    (wide)                 |                          |
|                      |                  door7                        |
|                      |                  (wide)                       |
|       room4          |        room5       |        room6             |
----------------------------------door8(wide)-------------door9----------
|                      |                    |                          |
|      light switch7  -|- light switch8     |- light switch9           |
|                      |                    |                          |
|                    door10                 |                          |
|                    (wide)                 |                          |
|                      |                  door11                       |
|                      |                  (wide)                       |
|       room7          |        room8       |        room9             |
------------------------------------------------------------------------
```

<p style="text-align:center">SRI Shakey's World 9 rooms</p>

Problems

Here are just the relevant inforations to understand the problems. For the complete description, please refer to the Shakey_probX.pddl files.

— *Shakey_prob1.pddl* : 3 rooms, 3 balls

```
(:init (in box room-2) (in ball-1 room-1) (in ball-2 room-2)
  (in ball-3 room-2) (in shakey room-1))

(:goal (and(in ball-1 room-3)
  (in ball-2 room-1) (in ball-3 room-3)(in shakey room-3)))
```

— *Shakey_prob2.pddl* : 3 rooms, 6 balls

```
(:init (in box room-2) (in ball-1 room-1)
  (in ball-2 room-2) (in ball-3 room-2) (in ball-4 room-1)
  (in ball-5 room-2) (in ball-6 room-3) (in shakey room-1))

(:goal (and(in ball-1 room-3)
  (in ball-2 room-1) (in ball-3 room-3)(in ball-4 room-3)
  (in ball-5 room-1) (in ball-6 room-1)(in shakey room-3)))
```

— *Shakey_prob3.pddl* : 3 rooms, 12 balls

```
(:init (in box room-2) (in ball-1 room-1)
  (in ball-2 room-2) (in ball-3 room-2) (in ball-4 room-1)
  (in ball-5 room-2) (in ball-6 room-3) (in ball-7 room-1)
  (in ball-8 room-2) (in ball-9 room-2) (in ball-10 room-1)
  (in ball-11 room-2) (in ball-12 room-3) (in shakey room-1))

(:goal (and(in ball-1 room-3)
  (in ball-2 room-1) (in ball-3 room-3)(in ball-4 room-3)
  (in ball-5 room-1) (in ball-6 room-1)(in ball-7 room-3)
  (in ball-8 room-1) (in ball-9 room-3)(in ball-10 room-2)
  (in ball-11 room-3) (in ball-12 room-1)(in shakey room-3)))
```

— *Shakey_prob4.pddl* : 9 rooms, 1 ball

```
(:init (in box room-1) (in ball-1 room-3) (in shakey room-2))

(:goal (in ball-1 room-9))
```

— *Shakey_prob5.pddl* : 9 rooms, 3 balls

```
(:init (in box room-1) (in ball-1 room-3) (in ball-2 room-6)
  (in ball-3 room-9) (in shakey room-2))

(:goal (and(in ball-1 room-9) (in ball-3 room-1) (in ball-2 room-7)))
```

— *Shakey_prob6.pddl* : 9 rooms, 6 balls

```
(:init (in box room-1) (in ball-1 room-3) (in ball-2 room-6)
  (in ball-3 room-9) (in ball-4 room-3) (in ball-5 room-3)
  (in ball-6 room-9) (in shakey room-2) (movable shakey))

(:goal
  (and(in ball-1 room-9) (in ball-3 room-1) (in ball-2 room-7)
  (in ball-4 room-9) (in ball-5 room-7) (in ball-6 room-2)))
```

Results

Test protocol : all tests have been done in the same conditions, on the same computer.

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