02285 AI and MAS
Exercises for week 2, 9/2-16

Exercise 1 (Planes and airports)

Solve exercise 10.2: “Given the action schemas and initial state from Figure 10.1, what are all the applicable concrete instances of $Fly(p, from, to)$ in...”

Exercise 2 (Simplified Gripper domain)

This exercise refers to the simplified Gripper domain used in today’s lecture.

a) The domain was in the lecture declared using two symmetric actions $MoveAB(x)$ and $MoveBA(x)$. Write the actions schema for a single action $Move$ that is able to replace $MoveAB$ and $MoveBA$. You might have to introduce additional variables and predicates.

b) Using $Move$ instead of $MoveAB$ and $MoveBA$ is likely to affect also the description of the initial state. Provide the new initial state of the simplified Gripper planning problem with n boxes initially located in location A.

c) Assume s is a state resulting from the execution of some sequence of $Move$ actions in the initial state. Show that if $In(\alpha, \beta)$ is a literal in s, then α is a constant denoting a box and β is a constant denoting a location. (If this doesn’t hold, go back to the first question and revise your action schema).

d) Does you $Move$ action allow moving a box from a location to itself, e.g. moving box 1 from location A to location A (in one action)? If so, revise your action schema.

e) Calculate the state space of the simplified Gripper planning problem with $n = 3$. To save space, you can exclude mentioning the rigid atoms in your states. A *rigid atom* is one that can never change truth value, like $Box(i)$ for $i = 1, \ldots, n$ in the formalisation of the simplified Gripper problem used in the slides.

f) The *branching factor* of a planning problem is the maximum number of actions applicable in any state reachable from the initial state. What is the branching factor of the simplified Gripper problem as a function of n?

g) Consider a modified planning problem with three locations, A, B and C. It is assumed that any box can be moved from any location to any other location. Describe the planning problem where all n boxes initially are located in A and where the goal is to get the even-numbered boxes into B and the odd-numbered into C. How much do you need to change: Initial state? Action schema? Goal state?

h) Modify the planning problem from the previous question further so that a single $Move$ can only move a box from A to B, from B to A, from B to C or from C to B. You might again need additional predicates.

Exercise 3 (Sokoban)

Sokoban is a classic puzzle game. It corresponds to the hospital domain of the programming project (Assignment 3) with the following restrictions imposed:

- There is only one agent, agent 0.
- The only available actions are moves and straight-line pushes, that is, using the naming from `prog_proj_assignment.pdf` they are $Move(x)$ and $Push(x, x)$ where x can be any of N, W, S or E. In the following we will refer to $Push(x, x)$ as simply $Push(x)$.
- All boxes have the same letter (A) and the same color (blue).

a) Consider the level in Figure 1a. Let n denote the width of the level, that is the number of cells along the horisontal axis (including wall cells). Answer the following questions: 1) What is the branching factor of the level (cf. Exercise 1)?; 2) What is the length of the shortest solution in terms of n given in Θ-notation?; 3) What is the size of the state space in Θ-notation (i.e. how many different states can the level be in)?

b) Consider the level in Figure 1b. Let n denote the width and breadth of the level (it is assumed to be quadratic). Answer the same questions as you did for Figure 1a.

c) Consider the level in Figure 1c. Let n denote the width and breadth of the level. Answer the same questions as for Figure 1a and 1b.

```
+++++++++++++++
+OA          a+
+++++++++++++++
```

(a)

```
+++++++++++++
+           +
+           +
+           +
+           +
+           +
+           +
+OA        a+
+           +
+           +
+           +
+           +
+           +
+           +
+++++++++++++
```

(b)

```
+++++++++++++++
+ A          a+
+ A          a+
+ A          a+
+ A          a+
+ A          a+
+ A          a+
+OA          a+
+ A          a+
+ A          a+
+ A          a+
+ A          a+
+ A          a+
+ A          a+
+++++++++++++++
```

(c)

Figure 1: Three different Sokoban levels.

d) Write action schemas for the *Move* and *Push* actions. It is assumed that all cells of levels are uniquely named by constants, e.g. $L_{(i,j)}$ for the location at coordinates (i, j). If you find this question difficult, it might help you to solve Exercise 4 first.

e) Provide the description of a full planning problem induced by a (very) small level, that is, provide initial state and goal.

f) *Optional*: The size of a planning problem can be taken to be the length of the initial state plus the length of the action schemas plus the length of the goal. Show that the state space size of a Sokoban level can in some cases be exponential in the size of the planning problem defining it.

Exercise 4 (Shakey the robot)

Optional. Solve exercise 10.4: "The original STRIPS planner was designed to control Shakey the robot..."