

COMP4418, 2016 – Assignment 2

Due: Friday, 14 October, 23:59:59

Worth: $\frac{1}{3}$

1. [25 Marks] (Planning)










The game of *Lights Out* consists of a 5x5 grid of lights that can be turned on and off. Clicking on a light will toggle both itself and its four adjacent lights. The goal of the game is to switch off all the lights on the grid. A more complete description of the game can be found here:

[https://en.wikipedia.org/wiki/Lights_Out_\(game\)](https://en.wikipedia.org/wiki/Lights_Out_(game))

and can be played on-line here:

<http://www.logicgamesonline.com/lightsout/daily.php>

Importantly this game can be treated as a planning problem. Your task in this question is to approach a simplified version of the *Lights Out* game using the delete relaxation. Consider the following 3×3 *Lights Out* grid with 4 lights switched off and 5 lights switched on.

	1	2	3
1			
2			
3			

- (a) **(2 Marks)** We will use the following operator to formalise the planning domain in the classical representation:

name	abbreviation	meaning
<code>turn_on(X,Y)</code>	<code>ton(X,Y)</code>	Turn on the light at cell column X and row Y.
<code>turn_off(X,Y)</code>	<code>toff(X,Y)</code>	Turn off the light at cell column X and row Y.

Explain why we need separate operators for turning a light on and turning a light off. Why can we not express this by a single operator?

- (b) **(8 Marks)** Use the state features `off(X,Y)` (for light at cell column X and row Y is off) to define the preconditions and effects of these two operators.
- (c) **(2 Marks)** Express formally the initial state and the goal of this planning problem.
- (d) **(4 Marks)** The *delete relaxation* gives rise to a relaxed problem. Give the preconditions and effects of the operators and the representation of the goal in the relaxed problem.
- (e) **(9 Marks)** For each action applicable in the original problem, determine the resulting state. In each case, give the state feature representation of the state and compute the value of the delete relaxation heuristic.

2. [25 Marks] (Answer Set Programming)

Your task is to use ASP to solve a *Lights Out* planning problems such as described in question 1.

- (a) (5 Marks) First consider the following simplified program:

```
time(0).
cell(1..2).
on(1,0).
on(X,T+1) :- click(X,T), not on(X,T), cell(X), time(T).
on(X,T+1) :- not click(X,T), on(X,T), cell(X), time(T).
```

With the additional fact `click(2,0)` compute all stable models of this program. You must provide your working of how you computed the stable models.

Hint: You will first need to calculate the grounding of the program.

- (b) (5 Marks) Now consider a representation for the *Lights Out* game. The actions of the planning domain can be represented in ASP using the following action name:

name	meaning
<code>click(X,Y,T)</code>	Click the cell at column X and row Y at time T.

Encode the effects of these actions on the status of cells in the grid. To represent that a grid cell is turned on use the predicate `on(X,Y,T)` to stand for “cell at column X and row Y is on at time T”. For example, the following diagram corresponds to the facts about the following grid at the initial time 0: `on(1,1,0)`, `on(2,3,0)`.

	1	2	3	4	5
1					
2					
3					
4					
5					

Hint: To encode your action effects you are allowed to introduce auxiliary predicates.

- (c) (15 Marks) Using the clauses from (b), write a uniform ASP encoding for solving the planning problem described in question 1 for arbitrary $N \times N$ grid sizes and arbitrary initial states.

Use the ASP system **Clingo** to compute answer sets for your ASP program (each answer set will constitute a solution to the planning problem).

Clingo is installed on the CSE computers (as described in the lecture notes) or can be downloaded from <http://potassco.sourceforge.net/>.

Your ASP program must be parameterised using the **Clingo #const** syntax to allow for the size of the grid and the maximum time horizon to be varied. Use the following at the start of your program:

```
#const size=5.
#const time_horizon=10.
```

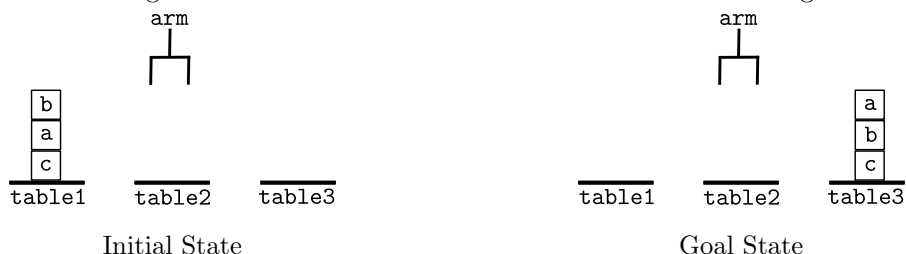
To test your program for varying grid sizes, time horizons, and problem instances:

```
clingo -c size=5 -c time_horizon=20 lightsout.asp data.asp
```

where `lightsout.asp` provides the uniform encoding of the problem and `data.asp` provides a particular problem instance.

3. [25 Marks] (Situation Calculus and GOLOG)

Consider the following *Blocksworld* planning problem: There are three tables with blocks **a**, **b** and **c** stacked on the far left table in some configuration. There is a robot arm that can pick up items from each table. The goal of the robot is to build the stack **a-b-c** on the far right table.



Additional assumptions:

- The arm can hold only one block at a time and can only access uncovered blocks.
- Each table has limited space so only a single block can be accommodated directly on a table.
- Unique name axioms are provided to guarantee the uniqueness of objects: **a**, **b**, **c**, **arm**, **table1**, **table2**, and **table3**.
- Use the following actions:

pickup(x)	Pickup block x .
putdown(x,y)	Place the currently held block x onto block or table y .

- (a) (4 Marks) Provide a description of the fluents (i.e., state predicates) required to represent the blocksworld domain (similar to the description of the actions above). It may also be useful to define some abbreviations. For example, a goal abbreviation could be defined to capture the desired goal state:

$\text{Goal(s)} \stackrel{\text{def}}{=} \dots \text{specification of desired stack configuration on table3} \dots$

- (b) (4 Marks) Use the Situation Calculus to specify a precondition axiom for each action.
- (c) (5 Marks) Use the Situation Calculus to specify a successor state axiom for each fluent.
- (d) (5 Marks) Define a **Goal(s)** abbreviation to specify the goal state and use this abbreviation to write a GOLOG procedure **solve1** that solves the Blocksworld planning problem for arbitrary initial situations.

Hint: Your GOLOG program can be written with the purpose of running it *off-line*.

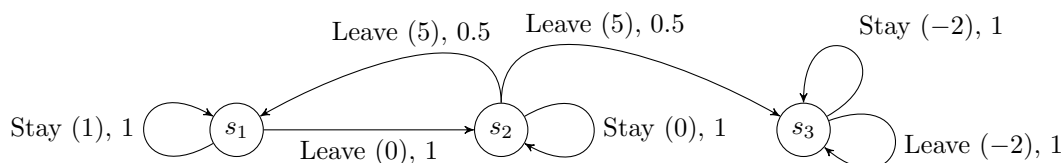
- (e) (7 Marks) **Hard question.** Write a GOLOG program to solve Blocksworld for arbitrary initial situations consisting of the following procedures:
- A procedure **pop(t,u)** that removes the top element off the stack on table **t** and places it onto the stack on table **u**.
 - A procedure **move(x,t)** that clears any blocks covering **x** (without changing the stack on table **t**) and then moves **x** to the stack on table **t**. This procedure should use **pop(t,u)**.
 - A solve procedure **solve2** that uses procedures **pop(t,u)** and/or **move(x,t)** to achieve the goal.

Hint: This question is hard because it may require a slightly more sophisticated modelling of the fluents for the domain in order to refer to the block at the top of a stack.

4. [25 Marks] (Decision Making)

- (a) (3 Marks) For each of the following games, choose the best model among (A) Markov chain (Markov process); (B) Markov decision process (MDP); (C) Hidden Markov model (HMM); (D) Partially-observable Markov decision process (POMDP); and (E) None/Other.
- Blackjack
 - Candy Crush
 - Chess
 - Minesweeper
 - Snakes and Ladders
 - Texas Hold 'em Poker

For the next questions, consider the Markov Decision Process depicted below. Edges are labelled “name of the action (reward associated), probability of the transition”.



- (b) (3 Marks) Using your intuition, give an optimal policy for situations where the discount factor is very high (for instance, $\delta = 0.999$)? Explain your reasoning in two or three sentences.
- (c) (3 Marks) Using your intuition, give an optimal policy for situations where the discount factor is very low (for instance, $\delta = 0.001$)? Explain your reasoning in two or three sentences.
- (d) (7 Marks) Represent the values computed during the first three iterations of the Value Iteration algorithm using the following format where L represents the action *Leave* and S represents the action *Stay*. Use a discounting factor of 0.6.

	$V_0(s)$	$V_0(s, S)$	$V_0(s, L)$	$V_1(s)$	$V_1(s, S)$	$V_1(s, L)$	$V_2(s)$	$V_2(s, S)$	$V_2(s, L)$	$V_3(s)$
s_1	0	1	...							
s_2	0	...								
s_3	0									

- (e) (3 Marks). Let π be the following policy: $\pi(s_1) = L$, $\pi(s_2) = L$, $\pi(s_3) = S$. If π is assumed to hold, the MDP turns into a Markov Chain. Represent this Markov Chain / Markov Process.
- (f) (6 Marks) Assuming the agent uses π , express the value associated to each state as a function of the discount factor δ . Provide the formal derivation of the result as part of your answer. Elaborate on whether the computations of this question support the intuition of questions 4b and 4c.

Submission

- Put your written solutions to questions 1, 2(a)–(b), 3 and 4 in a single PDF file `answers.pdf`
- Put your solution to 2(c) in a file `lightsout.asp`

Submit using the command:

```
give cs4418 a2 answers.pdf lightsout.asp
```

The deadline for this submission is 23:59:59 Friday 14 October.

Late Submissions

In case of late submissions, the maximum available mark is reduced by 10 points for each day late.

No extensions will be given for the assignment (except in case of illness or misadventure).

Academic Honesty and Plagiarism

All work submitted for assessment **must be your own work**. Assignments **must be completed individually**. We regard copying of assignments, in whole or part, as a very serious offence. Be warned that:

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- allowing another student to copy from you will, at the very least, result in a mark of zero for your own assignment; and
- severe or second offences will result in automatic failure, exclusion from the University, and possibly other academic discipline.

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