CMSC 671 (Introduction to AI) – Fall 2018

Homework 5: Knowledge and Planning

Please submit all parts I–IV together as a **single PDF file** named *lastname*_hw5.pdf, with parts clearly marked and delineated. Files must start with your last name and have your full name in the file, at/near the top. This is an individual homework—no groupwork, please.

PART I. KNOWLEDGE-BASED AGENTS (15 POINTS)

Remember the classic Minesweeper game (shown right)? In classic minesweeper, each square contains either a mine (if the agent explores this square, it loses the game), nothing, or a number ≥1 that indicates how many mines are in the 8 adjacent squares, and the agent's goal is to explore every unmined (safe) square and no mined squares. [1]

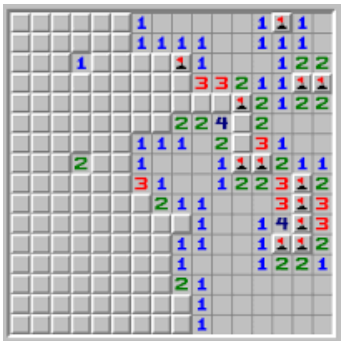

Figure 1. A partially finished game of classic Minesweeper.

We are considering, instead, the game Pony Minesweeper (shown right). In this variation, the agent's goal is different: it is attempting to find all the positive squares (the ponies), *without* stepping on any negative squares (the horse apples). The agent is not required to explore the entire map.

Figure 2. A partially finished game of Pony Minesweeper.

Assignment: Answer the following about a Pony Minesweeper agent.

1. Describe the Pony Minesweeper world according to the properties of task environments listed in Chapter 2 (i.e., the seven characteristics described in Section 2.3.2). Your answer should include a brief (single sentence or phrase) justification for each of the seven answers.

2. How would your answer change in a world in which horse apples could relocate to a different unexplored square between your moves, according to certain rules? Your answer should include a brief (single sentence or phrase) justification for each property *that changes*.

3. Now consider a variation of this world that contains a single **teleportation square**. The squares surrounding the drone are marked with a **t** as well as the numbers of ponies and horse apples. If the agent explores the square containing the teleporter, it teleports the agent to a randomly selected square. Does that change the environment description? Your answer should include a brief (single sentence or phrase) justification for each property *that changes*.

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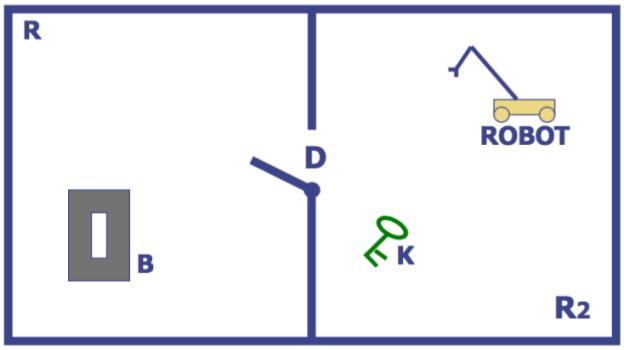
[1] If you are not familiar with classic minesweeper, search for online versions and play until you are sure you understand how it works. Instructions: www.minesweeper.info/wiki/Strategy, online game (one of many): michaelbutler.github.io/minesweeper

PART II. PLANNING (20 POINTS)

A robot ROBOT operates in an environment made of two rooms R1 and R2 connected by a door D. A box B is located in R2 and the door's key is initially in R2. The door can be open, or closed (and locked).

The initial state (shown, right) is given by:

IN(ROBOT,R2)
IN(K,R2)
OPEN(D)



The available actions are:

Grasp-Key-In-R2
Lock-Door
Go-From-R2-To-R1-With-Key
Put-Key-In-Box

The definitions of those actions are:

Grasp-Key-In-R2
P: IN(ROBOT,R2), IN(K,R2)
E: HOLDING(ROBOT,K)

Lock-Door
P: HOLDING(ROBOT,K), OPEN(D)
E: ~OPEN(D), LOCKED(D)

Go-From-R2-To-R1-With-Key
P: IN(ROBOT,R2), HOLDING(ROBOT,K), OPEN(D)
E: ~IN(ROBOT,R2), ~IN(K,R2), IN(ROBOT,R1), IN(K,R1)

Put-Key-In-Box
P: IN(ROBOT,R1), HOLDING(ROBOT,K)
E: ~HOLDING(ROBOT,K), ~IN(K,R1), IN(K,B)

The robot's goal is:

IN(K,BOX), LOCKED(D)

Assignment: Construct a partial-order plan to solve this problem. Clearly indicate at each step the modifications made to the plan: the action added, the causal links added and/or the ordering constraints added. Indicate any threats at each step.

PART III. FOL & INFERENCE (35 POINTS)

Assignment: Construct the following knowledge base (list the sentences in it).

4. Represent the following knowledge base *in first-order logic*. Use the predicates:

   - `is-faculty(x)`
   - `is-chair(x)`
   - `knows(x,y)`
   - `is-person(x)`
   - `is-friend-of(x,y)`
   - `criticizes(x,y)`

   where arguments `x` and `y` have the domain of all people. Note that `friend-of` and `criticizes` are one-way: `x` can be a friend of `y` without `y` being a friend of `x`. `knows`, however, is two-way.

   a. Dr. M is a faculty member.
   b. All faculty members are people.
   c. Dr. Joshi is the department chair.
   d. Department chairs are faculty members.
   e. Everyone is a friend of someone.
   f. All faculty members either consider the chair a friend or don't know him.
   g. People only criticize people that are not their friends.
   h. Dr. M criticized Dr. Joshi.

5. Convert the KB to conjunctive normal form (list the new set of sentences in the KB).

Assignment: Next, we wish to determine whether Dr. Joshi knows Dr. M.

6. Write the query in first-order logic.

7. Express the negation of the query in conjunctive normal form.

8. Add the negated goal to the KB, and use forward chaining to prove that it is true. Show your proof as a series of sentences to be added to the KB. (Denote new sentences with letters starting after k.) You must clearly show which sentences are used to produce each new sentence.

Assignment: Answer the following questions *in English*.

9. For two of the sentences in the KB, give a 1-2 sentence explanation of how those sentences are a poor representation of the real world.