CMSC 671 (Introduction to AI)—HW 4, Fall 2024

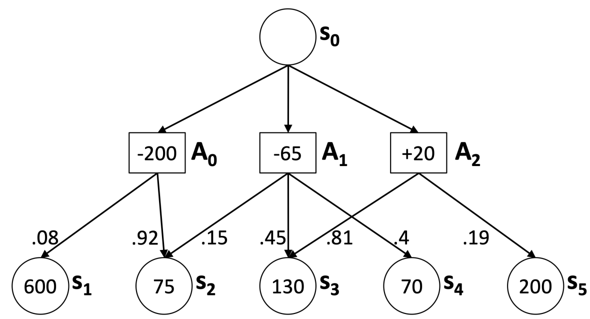
Turnin: Blackboard.

Please submit **all parts** together as a **single PDF file** named *lastname*_hw4.pdf, with parts clearly marked and delineated. This assignment should be worked on individually.

All files must start with your last name(s) and have your full name(s) in the file, at/near the top.

Part I. Decision Making Under Uncertainty (10 pts.)

Consider an agent that is trying to make a decision about what action to take, given a variety of possible actions and possible outcomes. The agent starts in state $\mathbf{s_0}$ and, based on the action it takes, will end up in one of $\mathbf{s_1}$–$\mathbf{s_5}$, each of which has an associated utility (shown in the circle). Each action $\mathbf{A_0}$–$\mathbf{A_2}$ has an associated cost (shown in the box), and probabilities of possible outcomes; for example, $\mathbf{A_0}$ has a P=0.08 chance of leading to state $\mathbf{s_0}$ and a P=0.92 chance of leading to $\mathbf{s_1}$.



1. What is the expected utility of action $\mathbf{A_1}$? *(3 pts)*

2. Using the principle of maximum expected utility, what action should the agent take? (Show all work.) *(7 pts)*

Part II. Proofs in Propositional Logic (15 pts.)

Use rules of inference to prove the following statements from the given KB. The most important rules of inference are given in the box below. Similar example proofs were performed in class and called out as likely homework problems; yours should look similar, with the logical statement you are adding to the KB on the left and the justification on the right.

3. KB: $\neg(s \land t)$ (premise 1)
   $\neg w \Rightarrow t$ (premise 2)

   Prove: $s \Rightarrow w$

4. KB: $\neg(\neg p \lor q)$ (premise 1)
   $\neg z \Rightarrow \neg s$ (premise 2)
   $(p \land \neg q) \Rightarrow s$ (premise 3)
   $\neg z \lor r$ (premise 4)

   Prove: r

Rules

Modus Ponens	A, A ⇒ B	B
And Introduction	A, B	A ∧ B
And Elimination	A ∧ B	A
Double Negation	¬¬A	A
Unit Resolution	A ∨ B, ¬B	A
Resolution	A ∨ B, ¬B ∨ C	A ∨ C
de Morgans	¬(A ∨ B)	¬A ∧ ¬B
∨/⇒ Equivalence	A ⇒ B	¬A ∨ B

PART III. PROPOSITIONAL LOGIC IN WUMPUS WORLD (15 PTS.)

We will use the definition of the Wumpus World given in class: that is, there is a single wumpus somewhere in the maze, along with multiple pits. At each square, a set of five percepts is given (but you only need to consider the ones shown in the sample map below). A wumpus and a pit may occupy the same square. The percept S*ij* means there is a stench in cell *i, j*; the percept B*ij* means there is a breeze in cell *i, j*; and V*ij* means cell *i, j* has been visited.

Rules

- If there is no stench in a cell, then there is no wumpus in any adjacent cell.
- If there is a stench in a cell, then there is a wumpus in some adjacent cell.
- If there is no breeze in a cell, then there is no pit in any adjacent cell.
- If there is a breeze in a cell, then there is a pit in some adjacent cell.
- If a cell has been visited, it has neither a wumpus nor a pit.

V13 S13 B13			
V12 ¬S12 ¬B12	V22 S22 B22		
V11 ¬S11 ¬B11	V21 ¬S21 ¬B21	V31 ¬S31 B31	

Given the observations shown and the rules given, and using the same rules of inference as above:

5. Can you prove there is a pit in square (3,2)? Why or why not? *(5 pts)*

6. Prove the Wumpus is in square (2,3). *(10 pts)*

PART IV. PLANNING (15 PTS.)

Consider the following four operators (from the textbook):

Operators

	RightShoe	RightSock	LeftShoe	LeftSock
preconds:	RightSockOn	-	LeftSockOn	-
adds:	RightShoeOn	RightSockOn	LeftShoeOn	LeftSockOn
deletes:	-	-	-	-

7. Define additional operators for putting on a shirt, hat, and coat, assuming that you must have a coat on before you can put a hat on. Give preconditions, additions, and deletions for your new operators. *(5 pts)*

8. Give (that is, draw) a partially ordered plan that is a solution to the problem of getting dressed (wearing all seven different articles of clothing). Assume that you start the plan wearing none of them. Do not give a single linear plan. *(5 pts)*

9. Give one linearized plan derived from the partially ordered plan in question 2. *(5 pts)*

PART V. FOL & INFERENCE (35 POINTS)

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

Use these predicates:

- `police(x)`
- `weapon(x)`
- `gun(x)`
- `sells-to(x,y,z)`
- `criminal(x)`
- `informs(x)`
- `possesses(x,y)`
- `informant(x)`

KB:

a. A police officer who sell weapons to informants is a criminal.
b. Mr. Jones has guns.
c. All of the guns were sold to Mr. Jones by Ms. Smith.
d. Guns are weapons.
e. Anyone who provides information (`informs`) is an informant.
f. Mr. Jones provides information.
g. Ms. Smith is a police officer.

10. Represent the following knowledge base *in first-order logic*. *(7 pts)*

11. Convert the KB to conjunctive normal form (list the new set of sentences in the KB). *(7 pts)*

Next, we wish to determine whether Ms. Smith is a criminal.

12. Write the query in first-order logic. *(3 pts)*

13. Express the negation of the query in conjunctive normal form. *(3 pts)*

14. 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 g.) You must clearly show which sentences are used to produce each new sentence. *(15 pts)*