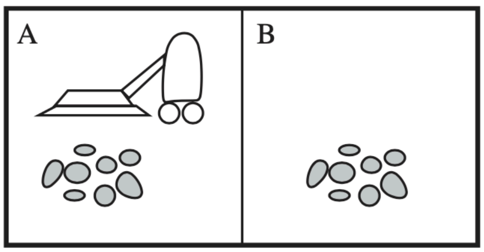
CSE 3521/5521
HW 3
Total : 100 points

Problem 1: [20 points]

Consider a modified version of the vacuum environment for the following figure, in which the agent is penalized one point for each movement.



a) Can a simple reflex agent be perfectly rational for this environment? Explain. [5 points]
b) What about a reflex agent with state? Design such an agent. [10 points]
c) How do your answers to a and b change if the agent's percepts give it the clean/dirty status of every square in the environment? [5 points]

Problem 2: [8 points]

Which of the following are true and which are false? Explain your answers.

a) Depth-first search always expands at least as many nodes as A^* search with an admissible heuristic.
b) A^* is of no use in robotics because percepts, states, and actions are continuous.
c) Breadth-first search is complete even if zero step costs are allowed.
d) Assume that a rook can move on a chessboard any number of squares in a straight line, vertically or horizontally, but cannot jump over other pieces. Manhattan distance is an admissible heuristic for the problem of moving the rook from square A to square B in the smallest number of moves.

Problem 3: [14 points]

n vehicles occupy squares (1, 1) through (n, 1) (i.e., the bottom row) of an n × n grid. The vehicles must be moved to the top row but in reverse order; so the vehicle i that starts in (i,1) must end up in (n−i+1,n). On each time step, every one of the n vehicles can move one square up, down, left, or right, or stay put; but if a vehicle stays put, one other adjacent vehicle (but not more than one) can hop over it. Two vehicles cannot occupy the same square.

a) Calculate the size of the state space as a function of n. [2 points]
b) Calculate the branching factor as a function of n. [2 points]
c) Suppose that vehicle i is at (x_i, y_i); write a nontrivial admissible heuristic h_i for the number of moves it will require to get to its goal location $(n - i + 1, n)$, assuming no other vehicles are on the grid. [4 points]
d) Which of the following heuristics are admissible for the problem of moving all n vehicles to their destinations? Explain. [6 points]

(i) $\sum_{i=1}^{n} h_i$.
(ii) $\max\{h_1, \ldots, h_n\}$.
(iii) $\min\{h_1, \ldots, h_n\}$.

<u>Problem 4: [12 points]</u>

In the following, a "max" tree consists only of max nodes, whereas an "expectimax" tree consists of a max node at the root with alternating layers of chance and max nodes. At chance nodes, all outcome probabilities are nonzero. The goal is to *find the value of the root* with a bounded-depth search. For each of (a)–(f), either give an example or explain why this is impossible.

a) Assuming that leaf values are finite but unbounded, is pruning (as in alpha–beta) ever possible in a max tree?
b) Is pruning ever possible in an expectimax tree under the same conditions?
c) If leaf values are all nonnegative, is pruning ever possible in a max tree? Give an example, or explain why not.
d) If leaf values are all nonnegative, is pruning ever possible in an expectimax tree? Give an example, or explain why not.
e) If leaf values are all in the range [0, 1], is pruning ever possible in a max tree? Give an example, or explain why not.
f) If leaf values are all in the range [0, 1], is pruning ever possible in an expectimax tree?

<u>Problem 5: [6 points]</u>

Consider the following sentence:

[(Food ⇒ Party) ∨ (Drinks ⇒ Party)] ⇒ [(Food ∧ Drinks) ⇒ Party] .

a) Determine, using enumeration, whether this sentence is valid, satisfiable (but not valid), or unsatisfiable.
b) Convert the left-hand and right-hand sides of the main implication into CNF, showing each step, and explain how the results confirm your answer to (a).
c) Prove your answer to (a) using resolution.

Problem 6: [14 points]

Consider a vocabulary with the following symbols:

- Occupation (p, o): Predicate. Person p has occupation o.
- Customer (p1, p2): Predicate. Person p1 is a customer of person p2.
- Boss (p1, p2): Predicate. Person p1 is a boss of person p2.
- Doctor, Surgeon, Lawyer, Actor: Constants denoting occupations.
- Emily, Joe: Constants denoting people.

Use these symbols to write the following assertions in first-order logic:

a) Emily is either a surgeon or a lawyer.
b) Joe is an actor, but he also holds another job.
c) All surgeons are doctors.
d) Joe does not have a lawyer (i.e., is not a customer of any lawyer).
e) Emily has a boss who is a lawyer.
f) There exists a lawyer all of whose customers are doctors.
g) Every surgeon has a lawyer.

Problem 7: [6 points]

From "Horses are animals," it follows that "The head of a horse is the head of an animal." Demonstrate that this inference is valid by carrying out the following steps

a) Translate the premise and the conclusion into the language of first-order logic. Use three predicates: HeadOf (h, x) (meaning "h is the head of x"), Horse (x), and Animal (x).
b) Negate the conclusion, and convert the premise and the negated conclusion into con- junctive normal form.
c) Use resolution to show that the conclusion follows from the premise.

Problem 8: [20 points]

After your yearly checkup, the doctor has bad news and good news. The bad news is that you tested positive for a serious disease and that the test is 99% accurate (i.e., the probability of testing positive when you do have the disease is 0.99, as is the probability of testing negative when you don't have the disease). The good news is that this is a rare disease, striking only 1 in 10,000 people of your age. Why is it good news that the disease is rare? What are the chances that you actually have the disease?