CSIT5900 Artificial Intelligence
Fall 2023 Final
19:30 - 22:30 on 7/12/2023
Time Limit: 3 hrs

Name: ______________________

Stu ID: ______________________

Instructions:

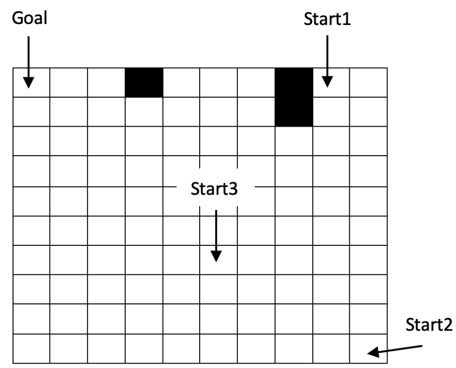
1. This exam contains 14 pages (including this cover page) and 10 questions.
2. This is a closed book exam. There are some copies of lecture notes in the end for your reference.
3. Observe the honor code.

Grade Table (for teacher use only)

Question	Points	Score
Reactive Agents and State Machines	10	
Perceptron Learning and GSCA Rule Learning	15	
Heuristic Search	12	
Alpha-Beta Pruning	5	
Games and RL	10	
MDP	10	
Uncertainty	10	
Propositional Logic	10	
FOL Representation	10	
Game Theory	8	
Total:	100	

Question 1: Reactive Agents and State Machines .... 10 points

Consider the robot with the same specification as our boundary-following robot discussed in class: eight sensors $s_1, ..., s_8$ and four actions ($North$, $South$, $East$, and $West$). Now suppose the environment is a 10x10 grid with an obstacle inside as shown below:



Suppose we want the robot to go to the **top left** corner labeled by "Goal". For each of the three starting positions labled in the figure, determine if this goal can be achieved by a reactive agent:

- If your answer is yes, give a production system for it. Do not call another production system. Write your own rules. When your production system is run with the given starting position, it will move the robot to the goal position, and as soon as it is in the goal position, it will stop (nil action).
- If your answer is no, give your reason for it.

Question 2: Perceptron Learning and GSCA Rule Learning .... 15 points

Consider the following data set:

ID	x_1	x_2	x_3	x_4	OK
1	1	0	1	0	Yes
2	0	0	1	0	Yes
3	1	0	0	0	No
4	1	1	0	1	No
5	0	1	1	1	No

where x_1, x_2, x_3 and x_4 are some features that should not concern us here.

2.1 (6 pts) Use these five instances to train a single perceptron using the error-correction procedure. Use the learning rate = 1, and the initial weights all equal to 0. Recall that the threshold is considered to be a new input that always have value "1". Please give your answer by filling in the following table, where weight vector (w_1, w_2, w_3, w_4, t) means that w_i is the weight of input x_i, and t is the weight for the new input corresponding to the threshold. Stop when the weight vector converges. If it doesn't converge, explain why not.

ID	Weight vector	Weighted Sum	Actual	Desired
Initial	0, 0, 0, 0, 0			
1				
2				
3				
4				
5				
...	...	...	...	...

2.2 (3 pts) What is the Boolean expression corresponding to your perceptron?

2.3 (6 pts) From the same training set, apply the GSCA algorithm to try to learn a set of rules. Give the set of rules if it succeeds. If it fails to learn a set of rules, explain why it failed.

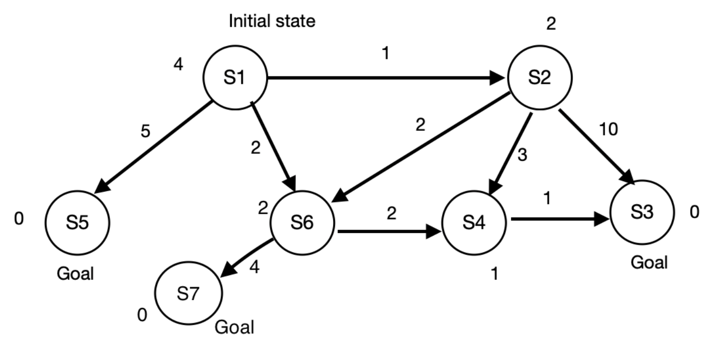
Question 3: Heuristic Search .... 12 points

Consider the following search problem, where the numbers on the edges are costs of the corresponding actions, and the numbers next to the states are their heuristic values.

3.1 (6 pts) Apply A* search by tree on this problem and give the solution returned by it. You can answer this question by drawing a search tree with the sequence of nodes selected for expansion clearly indicated. You can use any tie-breaking rule.

3.2 (3 pts) Can you come up with a new *admissible* heuristic function so that A* algorithm will return the solution $S1 \rightarrow S5$ without using any tie-breaking rule? If you can, provide such a heuristic function. If not, explain why not.

3.3 (3 pts) Can you come up with a heuristic function, admissible or not, so that A* will return the solution $S1 \rightarrow S6 \rightarrow S7$?



Question 4: Alpha-Beta Pruning .... 5 points

Consider the following game tree: Perform a left-to-right alpha-beta pruning. Which

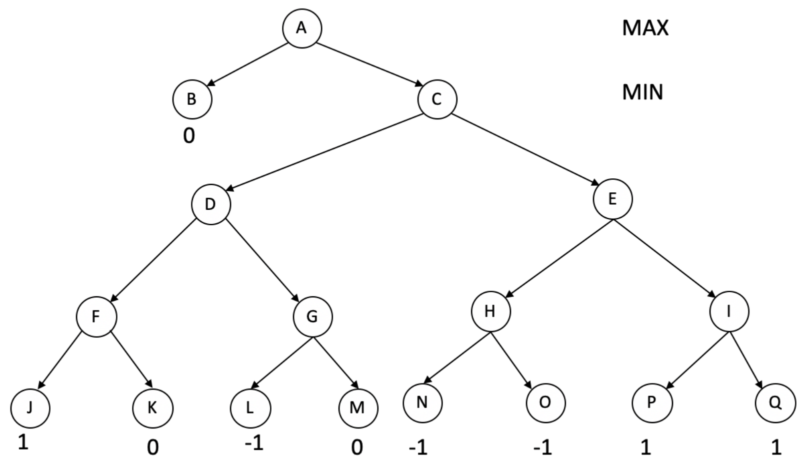


Figure 1: A minimax search tree

nodes are pruned? Notice that Left-to-right means that whenever a node is expanded, it's children are considered in the order from left to right.

Question 5: Games and RL . . . . 10 points

Consider the Tic-Tac-Toe game. Describe how you can train player X to play the game using reinforcement learning:

- Describe the states;
- Describe the actions that X can play in the states;
- Describe the starting state;
- Describe the end states;
- Describe what the transition probability function means, and whether it needs to be learned;
- Describe what the reward function means, and whether it needs to be learned

There are articles on the internet about using reinforcement learning to play the game. You can read as many of them as you want. In the end, if your answer uses some ideas from them, you have to cite them.

Question 6: MDP .... 10 points

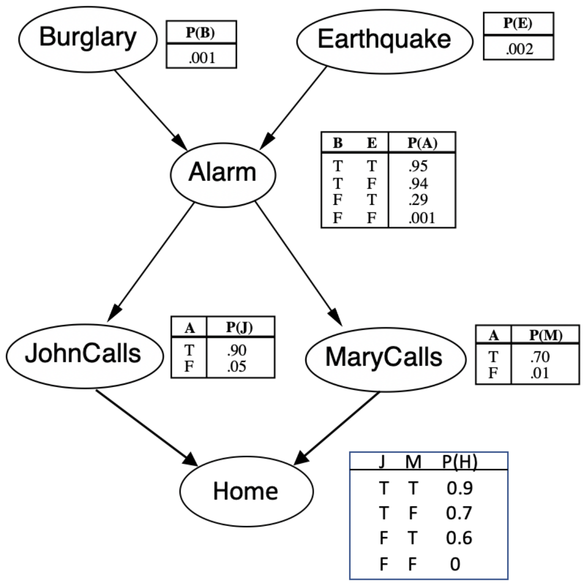
Imagine you are playing the following coin game. You can either quit, which will end the game and reward you \$10, or stay, which will reward you \$5 immediately and then a fair coin will be tossed. If it ends up with the head side up, then the game continues. If it ends up with the tail side up, then the coin will be tossed again. This time if it ends up with the head side up, then you pay \$9 (meaning your net loss is -\$4 in this case), and the game continues; but if it ends up with the tail side up, then the game ends. Answer the following questions by assuming the discount factor of 1.

6.1 (6 pts) Formulate this problem as a MDP.

6.2 (4 pts) Compute the optimal plan of your MDP.

Question 7: Uncertainty .... 10 points

Consider the following Bayesian network which adds one more node, *Home* (whether to go back home), to Pearl's example:



7.1 (5 pts) Are J (JohnCalls) and M (MaryCalls) independent given A (Alarm)? Explain your answer using D-separation.

7.2 (5 pts) Compute the probability of H (Home) being true given that A is true: $P(H|A)$. There is no need to perform numerical calculations. As long as your formula is right, you will get the full mark.

Question 8: Propositional Logic . . . . 10 points

A_1, A_2 and A_3 are three friends. We know the following facts about them:

- At least one of them is in the car.
- A_3 cannot drive.
- A_1 is in the car only if A_2 is in the car.

Use propositional logic to show that A_2 is in the car:

8.1 (5 pts) Encode the given facts as well as any necessary common sense knowledge as a KB using the following symbols:

- P_i: A_i is in the car, $i = 1, 2, 3$.
- D_i: A_i is the driver, $i = 1, 2, 3$.

8.2 (2 pts) Convert your KB to a set of clauses.

8.3 (3 pts) Use resolution (and proof by refutation) to show that your KB entails P_2.

Question 9: FOL Representation . . . . 10 points

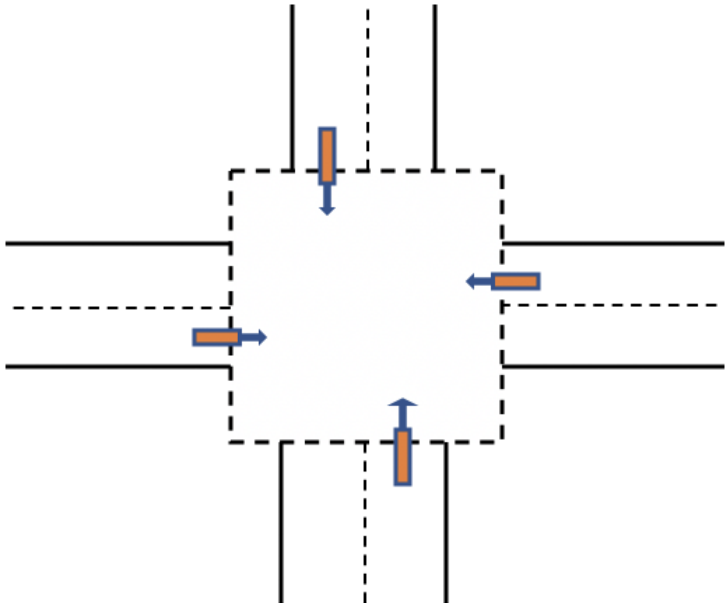
Given a graph, let predicate $e(x, y)$ stand for that nodes x and y have an edge connecting them, and function $c(x)$ for the color of node x. Let R, W and Y be three constants denoting colors red, white and yellow, respectively. Represent the following statements in first-order logic:

1. If two nodes are connected (by an edge), then they cannot have the same color.
2. The graph is fully connected, i.e. there is an edge between every pair of nodes.
3. A red node is conncted only to yellow nodes.
4. There is exactly one red node in the graph.
5. If a red node is connected with a yellow node, then it is also connected with a white node.

Note that we do not have an explicit node class. For example, when we write $\forall x \exists y . e(x, y)$, the variables x and y are understood to be nodes in the given graph. Note also that we assume the graph is undirected, so you can use either $e(x, y)$ or $e(y, x)$ to say that x and y are connected.

Question 10: Game Theory . . . . 8 points

Imagine 4 cars come to an intersection as illustrated in the following figure.



Each car can either stop or go. If two neighboring cars go at the same time, they will collide. Formulate this problem as a game in normal form and compute all its Nash equilibria.