COMP3211 Fundamentals of AI **Name:** _____
Fall 2020 Final
10/12/2020 **Stu ID:** _____
Time Limit: 170 Minutes

Instructions:

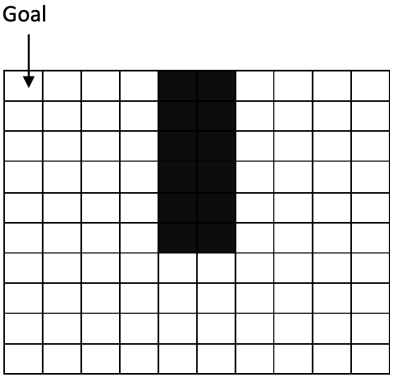
1. This exam contains 6 pages (including this cover page) and 9 questions.
2. Upload your answer to canvas as a pdf file (preferred) or a zip archive of image files (problem1.jpeg, problem2.jpeg,...) named by your student ID.
3. Observe the honor code - it's open book but no discussions or outside help are allowed.
4. Sign on the class zoom and turn on the video but mute the audio.
5. The exam starts at 12:30pm and ends at **3:20pm**. You will then have 10 minutes to upload your answers to canvas.

Grade Table (for teacher use only)

Question	Points	Score
Simple Agents	8	
Perceptron Learning and GSCA Rule Learning	12	
MDP	12	
Uncertainty	10	
Propositional Logic	10	
FOL	12	
Search	10	
Games and RL	12	
Concepts	14	
Total:	100	

Question 1: Simple Agents . . . . . 8 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, wherever its initial position is. We know that this cannot be done by a reactive (stimulus-response) agent (one of our midterm question).

1.1 We can let the robot remember the past k actions and sensor readings. What $k \leq 8$ will be sufficient for it to achieve this goal, wherever its initial starting position is? By achieving the goal we mean that the robot will eventually stop at this position. It is okay for it to visit this position more than once before it stops (*nil* action). Please briefly justify your answer informally. Of course, you can also justify it formally by giving, for example, a production system for achieving this goal, but this is not necessary. Notice that you do not need to come up with a minimal k. But you will not get any point if you just say, for example, $k = 8$ without any satisfactory explanation.

1.2 If you can add more sensors to the robot, what other sensors we can think of to make this goal achievable by a reactive agent? Again briefly justify your answer.

Question 2: Perceptron Learning and GSCA Rule Learning . . . . . 12 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 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 What is the Boolean function corresponding to your perceptron?

2.3 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: MDP ..... 12 points

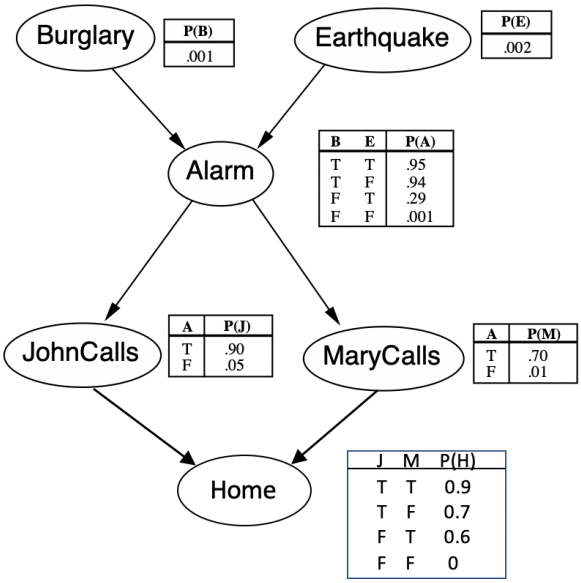
Imagine you are playing the following dice game. You can either quit, which will end the game and reward you \$10, or stay, which will reward you \$5 immediately and then a fair coin will be tossed. If it ends up with the head side up, then the game continues. If it ends up with the tail side up, then 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.

3.1 Formulate this problem as a MDP.

3.2 Compute the optimal plan of your MDP.

Question 4: Uncertainty ..... 10 points

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



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

4.2 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 5: 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:

5.1 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, $i = 1, 2, 3$.

5.2 Convert your KB to a set of clauses.

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

Question 6: FOL . . . . . 12 points

We know that Carol has no sisters, i.e. she is the only daughter of her parent. One day, someone saw Carol talking to a man and asked Carol whom she was talking to. Carol said that she was talking to a man whose mother is a daughter of my father. Use first-order logic to figure out the relationship between Carol and the man whom she was talking to.

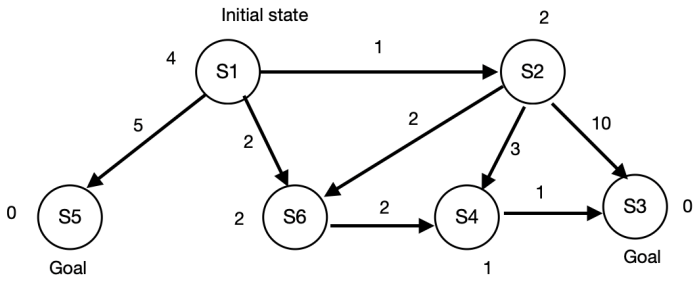
6.1 Encode the known facts, including what Carol said, as a KB using the following constants and predicates:
- C - constant denoting Carol.
- M - constant denoting the man whom Carol was talking to.
- $daughter(x, y)$ - x is y's daughter.
- $mother(x, y)$ - x is y's mother.

Important You are not allowed to introduce any other constants, functions or predicates.

6.2 What are the possible queries to your KB to find out the answer?

Question 7: Search . . . . . 10 points

Consider again the search problem in the midterm:



Recall that the numbers on the edges are costs of the corresponding actions, and the numbers next to the states are their heuristic values. Answer the following questions:

7.1 Can you come up with a new *admissible* heuristic function so that A* algorithm will return the solution $S1 \rightarrow S6 \rightarrow S4 \rightarrow S3$ without using any tie-breaking rule? If you can, provide such a heuristic function. If not, explain why not.

7.2 Can you come up with a new *admissible* heuristic function so that A* will expand only nodes that are on a path of an optimal solution regardless of any tie-breaking rule? More precisely, this means that using your heuristic function, if a node is selected from the OPEN list for expansion, then there must be an optimal plan that goes through this node. If you can, provide such a heuristic function. If not, explain why not.

Question 8: Games and RL ..... 12 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 9: Concepts ..... 14 points

In your own words, answer the following questions:

9.1 What is supervised machine learning?

9.2 What is unsupervised machine learning? Is it the same as clustering?

9.3 What is a linear predictor?

9.4 What is reinforcement learning?

9.5 What is the gradient descent algorithm?

9.6 What is genetic programming?

9.7 Is AI and same as machine learning? If yes, why? If not, list some differences.