*University No.:*______________________

THE UNIVERSITY OF HONG KONG

FACULTY OF ENGINEERING
DEPARTMENT OF COMPUTER SCIENCE

Final Exam

COMP7404 Computational Intelligence and Machine Learning

11 December 2021, 2:30 pm - 4:30 pm

Only approved calculators as announced by the Examinations Secretary can be used in this examination. It is the candidates' responsibility to ensure that their calculator operates satisfactorily, and candidates must record the name and type of the calculator used on the front page of the examination script.

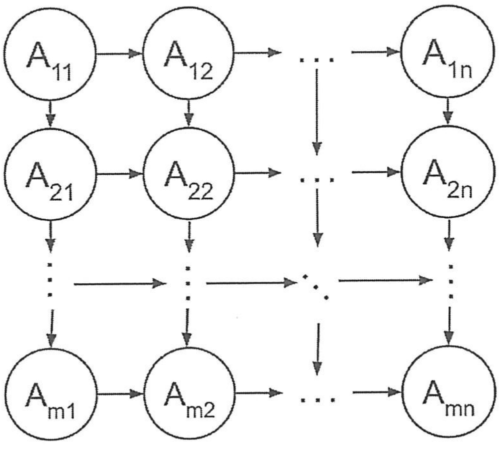
Calculator Brand: ______________ *Calculator Model:*______________

Answer all questions on this question paper in the space provided.
Write your University No. on every page.
Candidates are permitted to bring to the examination ONE sheet of A4-sized paper with printed or written notes on both sides.

Question	Max. Mark	Your Mark (examiner use only)
1	12	
2	8	
3	3	
4	4	
5	14	
6	4	
7	5	
Total	50	

1:

1.1: Consider the following directed graph that represents a class of search problems.
Let each edge have the same cost and let A_{11} be the start state and A_{mn} be the goal state. When answering the following questions, please assume $m > 2$, $n > 2$ and assume that the tree search algorithm is used (i.e., TSA). Use Big-O notation.



1.1.1 [1 mark]: Assume a directed graph. If we run Uniform Cost Search (UCS) what is the maximum size of the frontier?

1.1.2 [1 mark]: Assume a directed graph. If we run Depth First Search (DFS) what is the maximum size of the frontier?

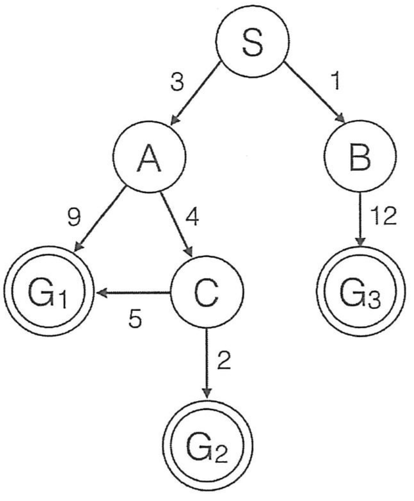
1.1.3 [1 mark]: Assume an undirected graph. If we run Uniform Cost Search (UCS) what is the maximum size of the frontier?

1.1.4 [1 mark]: Assume an undirected graph. If we run Depth First Search (DFS) what is the maximum size of the frontier?

1.2 [2 marks]: Which of the following statements are True? Select all True statements.

□ A* TSA is optimal, independent of the heuristic function
□ A* TSA is complete, independent of the heuristic function
□ An A* TSA implementation can be used to run UCS
□ A* GSA is guaranteed to expand no more nodes than DFS
□ A heuristic that always evaluates to h(s) = 1 for non-goal search nodes is admissible
□ The max of two admissible heuristics is always admissible

1.3: Consider the search graph and heuristics shown below. Let heuristics at goal states be 0 for all (i.e., H-1, H-2, H-3, H-4) heuristics.



	A	B	C	S
H-1	0	0	0	0
H-2	6	7	1	7
H-3	7	7	1	7
H-4	4	7	1	7

Let S be the start state and let G_1, G_2 and G_3 be goal states.

1.3.1: Write down the order of explored states assuming states are added to the frontier in alphabetical order.

1.3.1.1 [1 mark]: BFS

1.3.1.2 [1 mark]: DFS

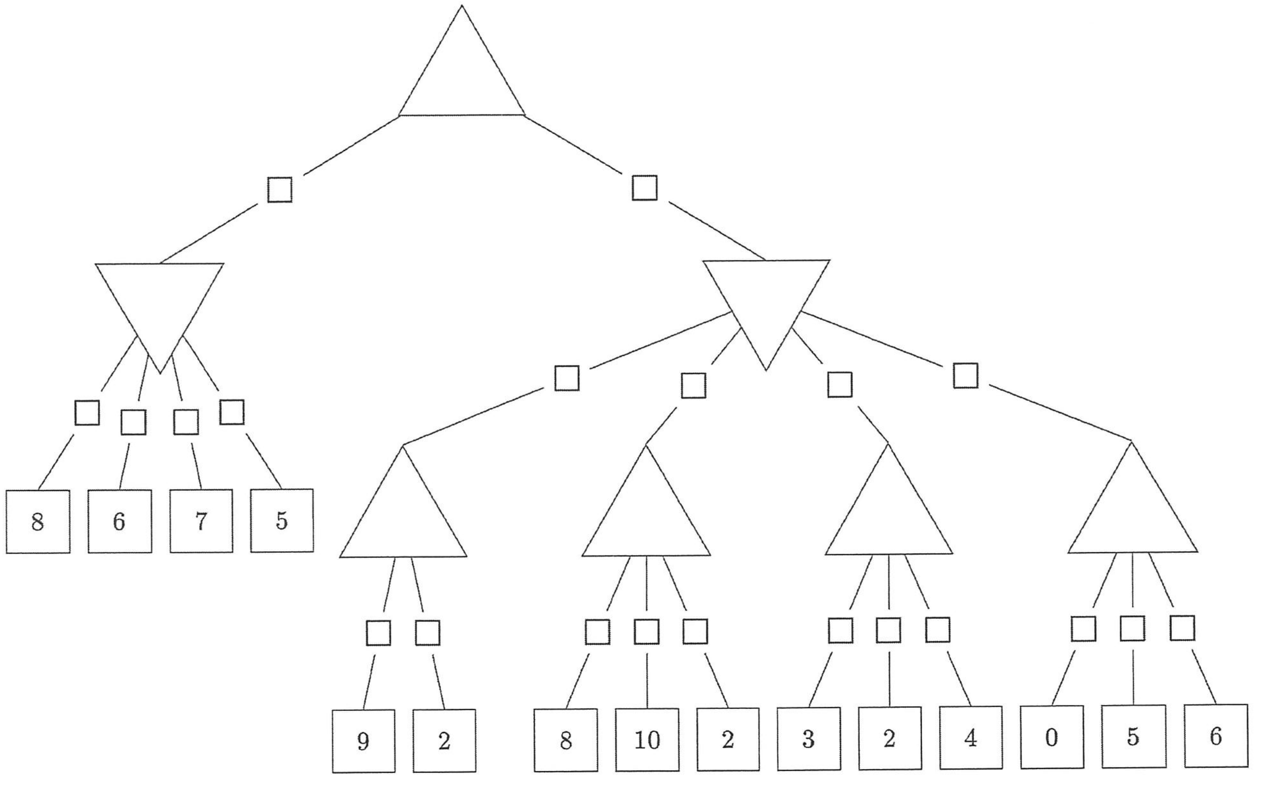
1.3.1.3 [1 mark]: A* with H-4

1.3.2: For each of the following heuristics, write down if it is consistent, admissible or neither.

1.3.2.1 [1 mark]: H-1

1.3.2.2 [1 mark]: H-4

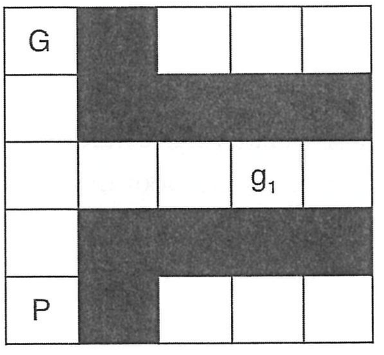
1.4 [1 mark]: Consider the following game tree.



Which nodes can be pruned by alpha-beta pruning? Mark the edge above each node that can be pruned (you do not need to mark any edges below pruned nodes). Assume children are evaluated left to right.

2: In the following, we will be using various gridworlds in which Pacman's starting position is denoted as P. G denotes the goal. At the goal, Pacman can only "Exit", which will cause Pacman to exit the Gridworld and gain reward +100.

2.1: Consider the following gridworld.



The Gridworld also has a gold nugget. Pacman will automatically pick it up if he enters the square that contains it. The gold nugget will add +10 to his reward, and he will receive +100 when he exits from the goal G as described above. Define P_0 as Pacman's initial state, where he is in position P and has no gold nuggets.

2.1.1 [2 marks]: When conducting value iteration, what is the first iteration at which V (P_0) is nonzero?

2.1.2 [2 marks]: Assume Pacman will act optimally. What nonzero discount factor γ ensures that the policy of picking up g_1 before going to goal G and the policy of going straight to G yield the same reward?

2.2: Consider the gridworld shown on the right.
Pacman now gets a living reward for every action he takes except the Exit action. Pacman receives +0 exiting from the Door (D), and +100 exiting from the Goal. Once in the Door square, Pacman can only Exit.

G				
P	D			

2.2.1 [2 marks]: Suppose $\gamma = 0.5$. For what living reward will Pacman receive the same reward whether he exits via the Door or exits via the goal?

2.2.2 [2 marks]: Suppose $\gamma = 0.5$. What is the living reward such that Pacman receives the same reward if he traverses the Gridworld forever or if he goes straight to and exits from the goal?

3:

3.1 [2 mark]: Consider an MDP with three states, A, B and C; and two actions CW and CCW. We do not know the transition function or the reward function for the MDP, but instead, we are given samples of what an agent actually experiences when it interacts with the environment (although, we do know that we do not remain in the same state after taking an action). In this problem, instead of first estimating the transition and reward functions, we will directly estimate the Q function using Q-learning. Assume the discount factor $\gamma = 0.5$ and the learning rate for Q-learning $\alpha = 0.5$. Let the current Q function, Q(s, a), be:

	A	B	C
CW	1.5	-2.5	-2.5
CCW	-1.5	-0.5	-2

The agent encounters the following samples:

s	a	s'	r
A	CCW	C	2.5
B	CW	A	1.5

Process the samples given above and write down all Q-values of the three states after both samples have been accounted for.

3.2 [1 mark]: In reinforcement learning, why can it be useful to sometimes act in a way which is believed to be suboptimal?

4:

4.1 [2 marks]: In this question you will use the Adaline algorithm discussed in class. Consider the following training samples

x1	x2	y
1	1	-1
1	-1	1
-1	1	-1
-1	-1	-1

Let initial weights all be equal to 0.4. Use a learning rate of 0.5.
Train two epochs using the provided training samples.

4.2 [2 marks]: Can you repeat 4.1 for the Perceptron by making minor changes to the training samples? If yes, perform two training epochs. If not, explain why it is not possible even with changes to the training samples.

5: Consider the following code that is employing the Iris dataset discussed in class and the sklearn library.

```
 1 from sklearn import datasets
 2 iris = datasets.load_iris()
 3 X = iris.data[:, [1, 3]]
 4 y = iris.target
 5 import numpy as np
 6 print('Class labels:', np.unique(y))
 7 from sklearn.model_selection import train_test_split
 8 X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2,
 9                                                      random_state=1, stratify=y)
10 print(X_train.shape)
11 print(X_test.shape)
12 print('Labels counts in y:', np.bincount(y))
13 print('Labels counts in y_train:', np.bincount(y_train))
14 print('Labels counts in y_test:', np.bincount(y_test))
```

5.1 [1 mark]: Explain line 3. What is the purpose of this line?

5.2 [1 mark]: What is the output of line 6. Explain.

5.3 [1 mark]: Explain the last two arguments to the function call in line 9.

5.4 [1 mark]: Write down the output of the line 10 to 14.

5.5 [1 mark]: Rewrite the program, by changing only a single line of code, such that only the first 100 samples of the iris dataset are used. Write down all output of this new program.

5.6: Consider a 2D dataset composed of a total of 14 samples of which 7 are positive and 7 are negative. Let the positive samples be (0.5,0.1), (0.6,0.2), (0.7,0.3), (0.8,0.4), (0.9,0.5), (0.2,0.7), (0.3,0.8) and the negative samples be (0.1,0.5), (0.2,0.6), (0.7,0.2), (0.4,0.8), (0.5,0.9), (0.8,0.3), (0.3, 0.7). Let all these samples be part of the training set except for the last negative sample which is part of the validation set. In this question, we are going to apply KNN with euclidean distance.

5.6.1 [2 marks]: Plot the dataset, denoting positive samples with + and negative samples with -. Circle samples that belong to the validation set and draw the decision boundary when K = 1.

5.6.2: What is the classification result on the validation sample for ...

5.6.2.1 [1 mark]: K = 2 ?

5.6.2.2 [1 mark]: K = 6 ?

5.6.2.3 [1 mark]: K = 13 ?

5.6.3: In general, what is the problem if K is …

5.6.3.1 [1 mark]: too small?

5.6.3.2 [1 mark]: too large?

5.7 [2 marks]: In the lecture slides we have seen the following term 1/2 |w|^2 for both SVM and Logistic Regression. For each of these models describe the purpose of this term.

6:

6.1 [2 marks]: In a medical application domain, suppose we build a classifier for patient screening (True means patient has cancer). Which of the following situations would you like your classifier to have? Select all correct answers. (FP: false positive, FN: false negative, TP: true positive, TN: true negative)

a) FP >> FN
b) FN >> FP
c) FN = FP × TP
d) TN >> FP
e) FN × TP >> FP × TN

6.2 [2 marks]: Suppose that there are a total of 60 machine learning related documents in a library of 200 documents. Now, suppose that a search engine retrieves 10 documents after a user enters 'machine learning' as a query, of which 5 are machine learning related documents. Write down the precision and recall for this example.

7:

7.1 [2 marks]: Say we have three models in an ensemble. We got the following results on a binary classification task.

Model Name	Class – 1 Probability	Class – 0 Probability
Model – 1	0.48	0.52
Model – 2	0.98	0.02
Model – 3	0.48	0.52

Apply soft voting and hard voting to this ensemble.

7.2 [1 mark]: If AdaBoost underfits the training data, which hyperparameter should be changed and how?

7.3 [1 mark]: For binary classification, which of the following statement(s) are true of AdaBoost with decision trees?

a) It usually has lower bias than a single decision tree
b) It can train multiple decision trees in parallel
c) It is popular because it usually works well even before any hyperparameter tuning

7.4 [1 mark]: For binary classification, which of the following statement(s) are true of AdaBoost?

a) It can be applied to neural networks
b) It uses the majority vote of learners to predict the class of a data point
c) The metalearner provides not just a classification, but also an estimate of the posterior probability

END OF PAPER

You may use the following blank space to draft your answer

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