THE UNIVERSITY OF HONG KONG

FACULTY OF ENGINEERING
DEPARTMENT OF COMPUTER SCIENCE

COMP7404 Computational Intelligence and Machine Learning

Date: May 21, 2015 **Time: 6:30pm - 8:30pm**

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:* ____________________

Write your University No. on every page.

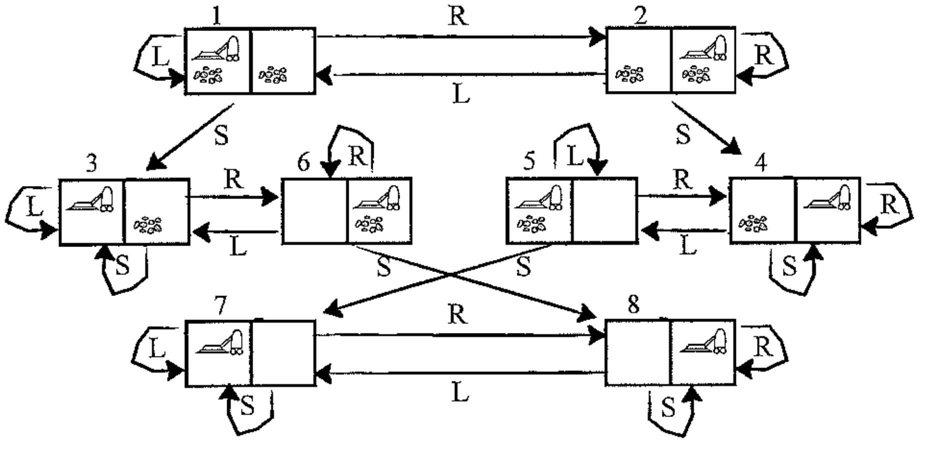
Answer all six questions in the space provided.

Special Note: Candidates are permitted to bring to the examination one sheet of A4-sized paper with hand-written notes on both sides.

Question No.	Weight (in %)	Your Mark (in %)
1	15	
2	26	
3	15	
4	20	
5	18	
6	6	
Total	100	

1. Search (Chapter 2)

(a) Consider the Vacuum World introduced in class. Let the search states of the problem be described by the locations of dirt and agent. The agent can perform the actions $left(L)$, $right(R)$ and $suck(S)$. The search space is visualized in the following figure.



State 7 and 8 are goal states and state 1 is the start state. If there is a draw, assume that actions are selected in the order L, R and S.

i. How many states will Depth First Search (Tree Search Algorithm) expand? *(2 marks)*

ii. Write down the order in which states will be expanded by Breadth First Search (Graph Search Algorithm). *(3 marks)*

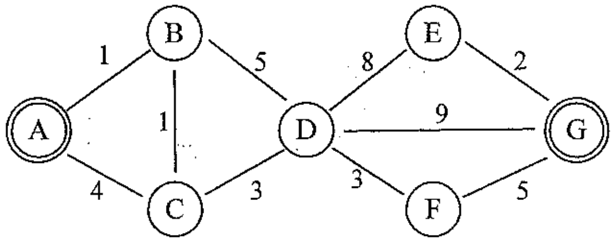
iii. Write down the order in which states will be expanded by Depth First Search (Graph Search Algorithm). *(3 marks)*

iv. The 1×2 Vacuum World above has 8 states. How many states are there for an $n \times m$ Vacuum World ($n, m \in \mathbb{N}$)? *(3 marks)*

(b) Depth Limited Search (Tree Search Algorithm) is often used as an alternative to Depth First Search (Tree Search Algorithm). Write down an advantage and a disadvantage of Depth Limited Search over Depth First Search. *(4 marks)*

2. More Search (Chapter 3)

(a) Consider the following state space graph where A is the start state and G is the goal state. Each edge can be traversed in both directions.



Let three heuristics h_1, h_2 and h_3 be given as follows.

	A	B	C	D	E	F	G
h_1	10	12	10	8	1	4.5	0
h_2	9.5	9	8	7	1.5	4	0
h_3	10	?	9	7	1.5	4.5	0

i. Is h_1 consistent? *(2 marks)*

☐ Yes

☐ No

ii. Is h_2 consistent? *(2 marks)*

☐ Yes

☐ No

iii. What values of $h_3(B)$ would make h_3 admissible? *(2 marks)*

iv. What values of $h_3(B)$ would make h_3 consistent? *(2 marks)*

v. For each of the following graph search strategies, mark which, if any, of the listed paths it could return. Note that for some search strategies the specific path returned might depend on tie-breaking behavior. In any such cases, make sure to mark all paths that could be returned under some tie-breaking scheme. *(6 marks)*

	A-B-D-G	A-C-D-G	A-B-C-D-F-G
Uniform Cost Search			
A^* with heuristic h_1			
A^* with heuristic h_2			

vi. Peter, a student in our class, has implemented the A* graph search algorithm incorrectly. His version of A* is identical to the correct A*, except that it declares completion when it first visits the goal node. Write down the path found by Peter's version of A* using h_2 as the heuristic. *(4 marks)*

(b) If $f(s)$, $g(s)$ and $h(s)$ are admissible heuristics, then which of the following are also guaranteed to be admissible heuristics. *(8 marks)*

- ☐ $f(s) + g(s) + h(s)$
- ☐ $f(s)/6 + g(s)/3 + h(s)/2$
- ☐ $min(f(s), g(s), h(s))$
- ☐ $max(f(s), g(s), h(s))$
- ☐ $f(s)/3 + g(s)/3 + h(s)/3$
- ☐ $f(s) * g(s) * h(s)$
- ☐ $min(f(s), g(s) + h(s))$
- ☐ $max(f(s), g(s) + h(s))$

3. Constraint Satisfaction Problems (Chapter 4)

(a) Consider a constraint satisfaction problem with three variables: A, B and C. Each of three variables can take one of two values: either 1 or 2. There are three constraints: $A \neq B$, $B \neq C$ and $A \neq C$. Write down the values of the variables that will be eliminated by enforcing arc consistency. *(4 marks)*

(b) You are in charge of assigning three teachers to five classes that will be taught on the same day. You are constrained by the fact that each teacher can only teach one class at a time. The classes are

- Class 1 - Data Mining: meets from 8am - 9am
- Class 2 - Computational Finance: meets from 8:30am - 9:30am
- Class 3 - Legal Protection of Digital Property: meets from 9am - 10am
- Class 4 - Digital Investigation and Forensics: meets from 9am - 10am
- Class 5 - Cluster and Cloud Computing: meets from 9:30am - 10:30am

The teachers available to teach these classes are

- Professor A, available to teach classes 3 and 4
- Professor B, available to teach classes 2, 3, 4 and 5
- Professor C, available to teach classes 1, 2, 3, 4 and 5

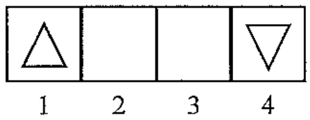
i. Formulate this problem as a constrained satisfaction problem (CSP) in which there is one variable per class. Draw the constraint graph, and state the domains and constraints. Constraints should be specified formally and precisely, but may be implicit rather than explicit. *(6 marks)*

ii. Write down the domains of the variables after running arc-consistency on the initial graph (after having already enforced any unary constraints). *(3 marks)*

iii. Write down the possible solutions to the CSP, if any. *(2 marks)*

4. Adversarial Search (Chapter 5)

(a) Two players, player $\triangle$ and player $\triangledown$, find themselves in the following start state of an adversarial game.

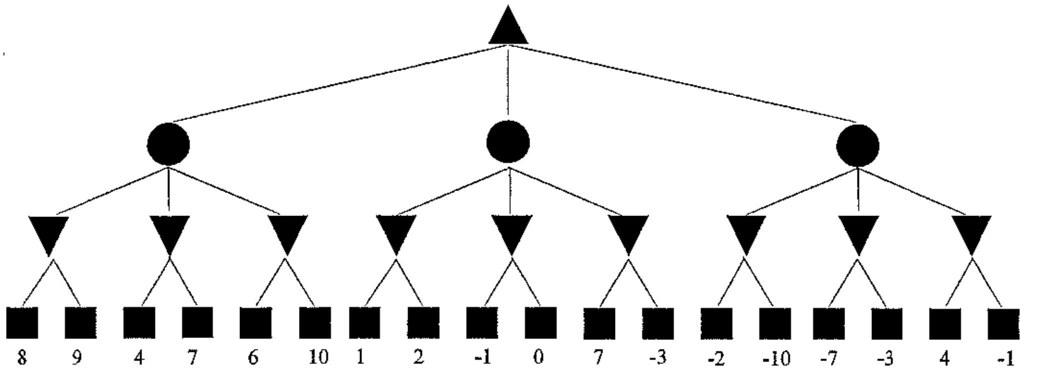


Player $\triangle$ moves first. The two players take turns moving, and each player must move to an open adjacent square in either direction. If the opponent occupies an adjacent space, then the player will jump over the opponent to the next open space, if any. For example, if player $\triangle$ is on square 3 and player $\triangledown$ on square 2, then player $\triangle$ may move back to square 1. The game ends when one player reaches the opposite end of the board. If player $\triangle$ reaches the square 4 first, then the value of the game is +1, if player $\triangledown$ reaches square 1 first, then the value of the game is -1.

i. Draw the minimax game tree and use the proper triangles to distinguish a *min* from a *max* node. Put terminal states in square boxes and loop states in double square boxes. Loop states are those that already appear on the path to the root. Write down the value of every state, you may write "*unknown*" for loop states. Can you indicate the optimal decision at the root of the tree? Explain. *(10 marks)*

ii. Consider an n-square game with $n > 2$ squares instead of the above 4-square game with 4 squares. How would the value at the root of the tree change? *(5 marks)*

(b) The following figure shows a complete game tree for a simple game. You may assume that the leaf nodes are to be evaluated in the left-to-right order. Let children of chance nodes be equally likely.



i. Write all values of the tree next to their nodes and indicate the best move at the root.

ii. This question considers pruning in games with chance nodes. Suppose that all leaf values fall in the range of $[+10, -10]$. Explain how these bounds might enable some leaf nodes to be pruned. Circle the branches that need not be evaluated. *(5 marks)*

5. Markov Decision Processes (Chapter 6)

Consider the following Grid World introduced in our lecture where an agent may move *north*, *south*, *east* or *west* and exit states are $a4$ and $b4$.

	1	2	3	4
a	-1.11	-1.10	-0.94	$+1$
b	-1.11		-1.10	-1
c	-1.11	-1.11	-1.11	-1.10

Actions are unreliable: 80% of time each action achieves the desired effect and 10% of the time the action moves the agent at right angles to the intended directions. If the agent runs into a wall, it stays in the same square. After running value iteration we have obtained the values shown in the figure. Note that values have been rounded to two decimal places. Let the discount factor $\gamma = 0.1$ and the reward R(s) = -1. Consider the two states $a3$ and $b3$.

(a) Show that values of the two states have converged. *(8 marks)*

(b) Calculate the Q-values of the two states. *(8 marks)*

(c) Perform policy extraction for the two states. *(2 marks)*

6. Reinforcement Learning (Chapter 7)

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 step size for Q-learning, $\alpha = 0.5$. Let the current Q function, $Q(s, a)$, be

	A	B	C
CW	0.3	-0.5	-2.5
CCW	0.0	-1.3	-1.9

The agent encounters the following samples

s	a	s'	r
A	CCW	C	9.0
B	CW	A	0.0

Process the samples given above and write down all Q-values of the three states after both samples have been accounted for. *(6 marks)*

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Please be reminded to write your university number on the first page.

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You may use it to draft your answers.