Artificial Intelligence
COMS4033A/7044A
Class Test

16 April 2024, 14h15–16h15, MSB006

Name: _____

Student Number: _____

For marking purposes only

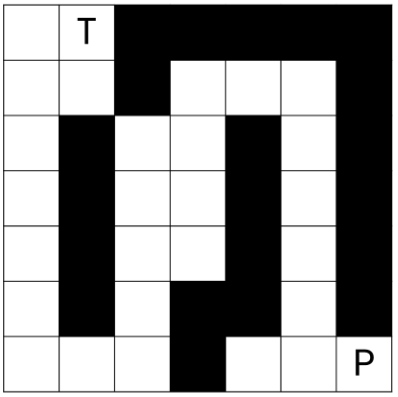
Question 1	
Question 2	
Question 3	
Question 4	
Total	

Instructions

- Answer all questions in pen. **Do not write in pencil.**
- This test consists of 10 pages. Ensure that you are not missing any pages.
- This is a **closed-book** test: you may not consult any written material or notes.
- You are allocated 2 hours to complete this test.
- There are 4 questions and 50 marks available.
- Ensure your cellphone is switched off.

Question 1 Agents and Search [16 Marks]

1. Consider applying search to a 2D maze where an agent must navigate to pick up a treasure hidden within the maze and return to the starting location to win the game. A visualisation of the problem is shown below, where P represents the player in its starting location, and T represents the treasure. Walls are indicated by the black regions.



Describe in words what the appropriate formulation of the problem is in terms of (a) the state space, (b) the set of actions, (c) the successor function (including the cost function), and (d) the goal test. [4]

2. Bob tells you that he intends to build a robot that will act exactly as a human. Would you classify such a robot as a "rational agent"? Why or why not? [1]

3. Consider the task of building an autonomous taxi driver. We can categorise this task along the following lines:

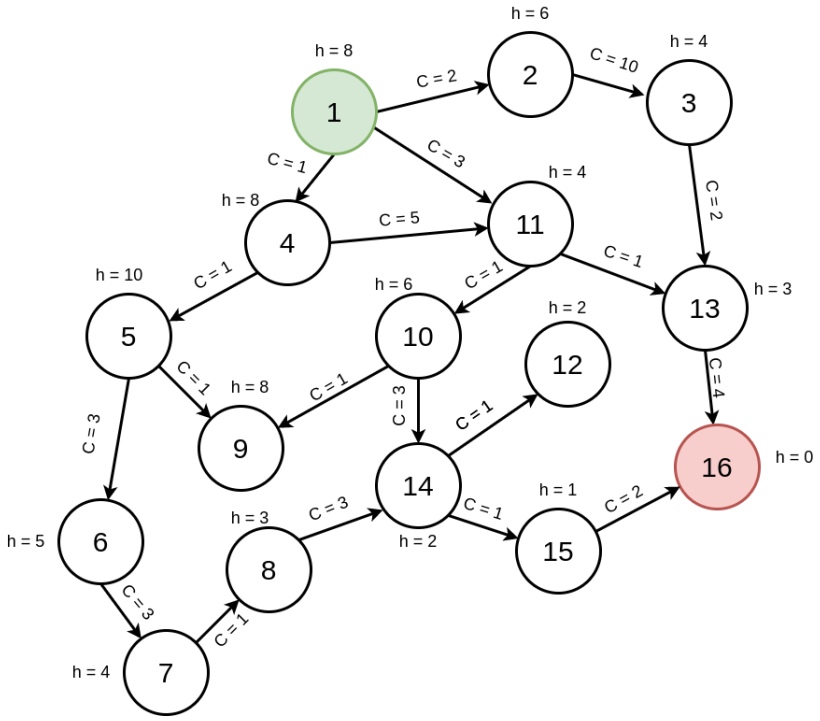
   (a) partially observable or fully observable
   (b) deterministic or stochastic
   (c) episodic or sequential
   (d) static or dynamic
   (e) discrete or continuous
   (f) single agent or multiagent

   For each option above, identify the correct one and motivate your answer. [3]

4. List two reasons why iterative deepening is typically used as the uninformed search algorithm of choice, when compared to alternatives such as breadth-first search or depth-first search. [2]

5. Let C be the cost of traversing an edge between nodes, and let h be the heuristic estimate of a given node to the goal. Consider the graph below, where nodes are labelled with integers and directed edges are indicated by lines with arrows. Each edge is labelled with a cost C, and each node with a heuristic value h.

   Assume that we wish to search for the goal node 16 starting at node 1 using the greedy-best-first search (GBFS) algorithm. Further, assume that if there are ties in the priority queue, they are resolved by removing the node with the smallest label first (e.g. if two nodes 2 and 1 both have priority 10, then 1 will be removed before 2).



Given this, detail each step of the search algorithm. At each iteration, describe what node is popped from the queue and then what nodes are added to the queue subsequently (and their corresponding priority). [4]

6. Imagine we have a set of admissible heuristics $h_1, h_1, \ldots, h_n$. For each of the following, state whether they would result in an admissible heuristic or not: [2]

   (a) $\sum_i h_i$

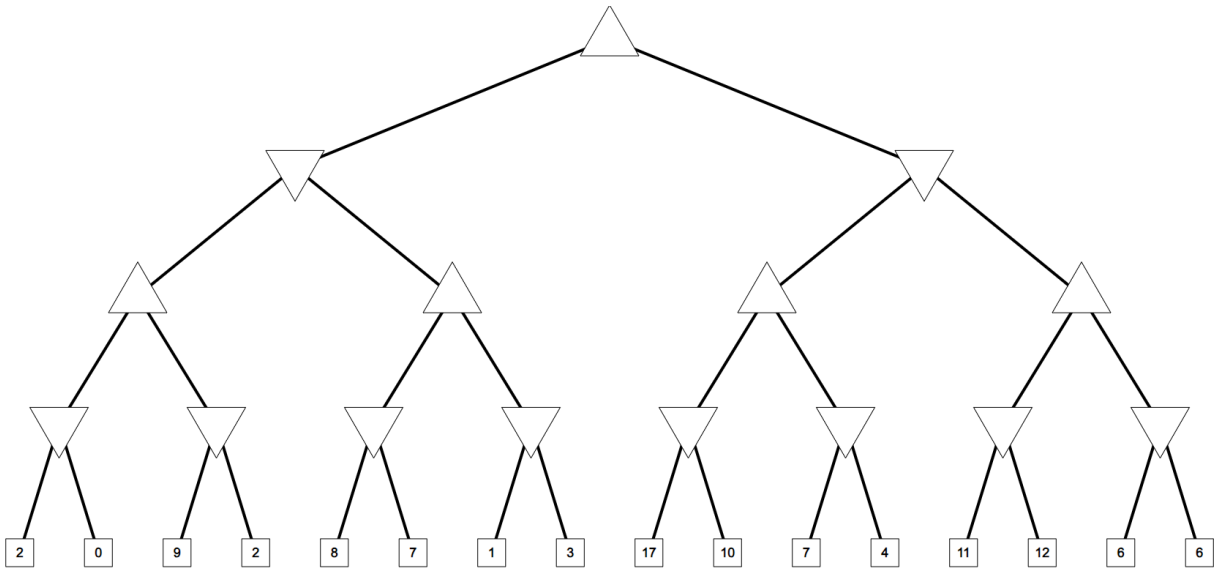
   (b) $\max_i h_i$

   (c) $\min_i h_i$

   (d) $\frac{\sum_i h_i}{n}$

Question 2 Game Theory [9 Marks]

1. Consider the game tree below. Triangles pointing up represent the maximising player, triangles pointing down are the minimising player and rectangles are terminal nodes. Execute alpha-beta pruning on the tree. Annotate the tree by writing down the value backed up to each node in the tree (including the root), and indicate where pruning takes place by crossing out the relevant edges. [5]



2. Consider the following payoff matrix representing a game between two players A (the "row" player) and B (the "column" player).

	B_1	B_2	B_3	B_4
A_1	$(1, 7)$	$(2, 5)$	$(7, 2)$	$(0, 1)$
A_2	$(5, 2)$	$(3, 3)$	$(5, 2)$	$(3, 1)$
A_3	$(7, 0)$	$(2, 5)$	$(0, 4)$	$(1, 1)$
A_4	$(0, 0)$	$(0, 2)$	$(0, 0)$	$(0, -1)$

   (a) Execute the *maximin* algorithm on the payoff matrix to find the outcome, beginning with player A. At each step, list the strategy selected by the relevant player, as well as the final outcome. [2]

(b) Repeat the above, but now begin with player B. What is the outcome of this procedure? [1]

(c) Are any of the strategies produced by the *maximin* algorithm for both players a Nash equilibrium? Motivate your answer. [1]

Question 3 Knowledge Representation [11 Marks]

1. In first-order logic, what is the difference between a *function* and a *predicate*? [1]

2. Encode the statement "everything is bitter or sweet" in first-order logic. [1]

3. Alice wishes to encode the idea that at least one person is alive. She writes this as $\exists x Person(x) \Rightarrow Alive(x)$. Explain the fault in her reasoning and then write down the correct logical sentence. [2]

4. In Johannesburg, 51% of adults are men. One adult is randomly selected for a survey by a local radio station. It is later learned that the selected survey subject was smoking a cigarette. In addition, 9.5% of men smoke cigarettes, whereas 1.7% of women smoke cigarettes. Use this additional information to find the probability that the selected subject is a man. [3]

5. Define what is means for p to entail q (i.e. $p \models q$). The, argue why for any α, $False \models \alpha$. [2]

6. Imagine you are attempting to model a point mass moving on an infinite 2D plane with some constant velocity, which we do not have access to. Your friend wishes to define the state of the system using the point's xy-coordinates. However, you point out that such a state representation is not Markov. (a) Why is this the case, and (b) how can you construct a state representation that *is* Markov? [2]

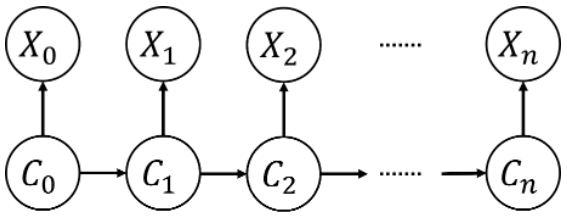
Question 4 Bayesian Networks [14 Marks]

1. A patient has been suffering from shortness of breath (called dyspnoea) and visits the doctor, worried that he has lung cancer and he has read that one of the symptoms of lung cancer is dyspnoea. The doctor knows that the chance of the patient having cancer (or some other disease) is affected by whether he is a smoker or has been exposed to air pollution. A positive X-ray would indicate lung cancer. We wish to model this using a Bayesian network with the following random variables: whether the patient has been exposed to pollution (`pollution`), whether they are a smoker (`smoker`), whether they have cancer (`cancer`) or dyspnoea (`dyspnoea`) and whether the X-ray returns a positive cancer diagnosis (`xray`).

   (a) Draw the corresponding Bayesian network for the above five variables. [2]

   (b) Write down the factorisation of joint probability distribution given the Bayesian network's structure in part a). [1]

2. Consider the Hidden Markov model with hidden states $\mathbf{C}$ and observations $\mathbf{X}$.



   (a) Write down $P(X_0, X_1, \ldots X_n, C_0, C_1, \ldots C_n)$ — the full joint probability distribution. [1]

(b) Imagine now that each hidden state C_t depended not just on C_{t-1} but also on C_{t-2}. What would the factorisation of the full joint probability be in this case? [1]

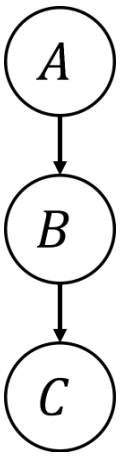
3. In the context of Hidden Markov Models, what is the difference between prediction and smoothing? Answer this question by writing down the probabilities that each approach attempts to calculate (and define your notation), and then suggest one real-world application for each of them. [3]

4. The output of the forward algorithm is an unnormalised probability over each state. Why is it not necessary to normalise these values? [1]

5. In words, describe the main difference between the forward algorithm and the Viterbi algorithm. [2]

6. Describe why a Bayesian network is referred to as a generative model. What does it generate, and how does this generation process proceed? [2]

7. Consider a Bayesian network, where each node is a Boolean random variable, and each node has exactly one parent (except the first one), resulting in a chain. An example of this structure for three variables is given below.



If this network instead had N nodes, how many entries would be required to complete the conditional probability tables for the network, and how many entries would be required by a full joint probability distribution? [1]

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