

NANYANG TECHNOLOGICAL UNIVERSITY**SEMESTER 1 EXAMINATION 2021-2022****CZ3005 – ARTIFICIAL INTELLIGENCE**

Nov/Dec 2021

Time Allowed: 2 hours

INSTRUCTIONS

1. This paper contains 4 questions and comprises 6 pages.
 2. Answer **ALL** questions.
 3. This is a closed-book examination.
 4. All questions carry equal marks.
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1. (a) State whether each statement is True (T) or False (F). Each question carries one mark.
 - (i) The 8-queens game is a discrete environment.
 - (ii) A Chess playing agent operates in a deterministic environment if there is no clock.
 - (iii) If a search algorithm can guarantee optimality, then it is also complete.
 - (vi) Autonomous driving is a discrete environment.
- (v) Depth-first search has lower space complexity as compared to breadth-first search.

(5 marks)

Note: Question No. 1 continues on Page 2

- (b) A* search uses heuristic function $h(n)$ which provides an estimated cost of the cheapest path from node n to a goal state $h(n)$. If $h(n)$ is not higher than the true cost, i.e., admissible, A* is also optimal. If two heuristic functions h_1 and h_2 are admissible and $h_2(n) \geq h_1(n)$ for all n , will A* expand more nodes if we use h_1 as compared with using h_2 ? Justify your answer. (8 marks)
- (c) Explain two key ideas that one uses for speeding up the search process for solving a constraint satisfaction problem. (6 marks)
- (d) Explain the key idea of Minimax and why the generated strategy is robust. (6 marks)
2. Assume we are an agent in a 2x3 Gridworld, as shown in Table Q2a. We start at the bottom left node (State 1) and finish at the top right node (State 6). When node 6 is reached, we receive a reward of +10. For all other actions that do not lead to state 6, the reward is -1.

Table Q2a

State 4	State 5	State 6 (Terminal State)
State 1 (Initial State)	State 2	State 3

In each state, we have four possible actions: up, down, left and right. Assume that we cannot take actions that bring us outside the grid.

The current estimates of $Q(s, a)$ where s is a state and a is an action are given in Table Q2b (we only show the legal actions and non-terminal states):

Table Q2b

$Q(1, \text{up})=4$			$Q(1, \text{right})=3$
$Q(2, \text{up})=6$		$Q(2, \text{left})=3$	$Q(2, \text{right})=8$
$Q(3, \text{up})=9$		$Q(3, \text{left})=7$	
	$Q(4, \text{down})=2$		$Q(4, \text{right})=5$
	$Q(5, \text{down})=6$	$Q(5, \text{left})=5$	$Q(5, \text{right})=8$

Note: Question No. 2 continues on Page 3

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- (a) Assume that for each action, we can move deterministically in the intended direction on the grid. Assume that the discount factor is 0.9. In value iteration, we update the value of each state by first updating the Q value of each state-action pair. Show the updated Q table after one round of value iteration and the updated value (V) of each state. Note that each new Q value is based on the old Q values in Table Q2b, i.e., we assume synchronous update. (9 marks)
- (b) Now suppose that we do not know the transition function. We will update the Q-table in Table Q2b with the Q-learning algorithm. Starting from state 2, we have sampled the following trajectory: state 2 – action up – state 5 – action right – state 6, after which the trial ends. Show how to apply Q-learning to update two Q(s, a) entries. Assume that the learning rate is 0.2 and the discount factor is 0.9. (8 marks)
- (c) Explain the key differences between the Monte Carlo approach and Q-Learning. (4 marks)
- (d) When we apply the Monte Carlo approach for learning a policy, why do we need to learn state-action values (Q) instead of just learning state values (V)? (4 marks)
3. (a) State whether the following statements are True (T) or False (F).
- (i) A knowledge base consists of a set of sentences written in the knowledge representation language. (1 mark)
- (ii) Propositional logic is the most advanced logic. (1 mark)
- (iii) A knowledge representation language consists of syntax and semantics. (1 mark)

Note: Question No. 3 continues on Page 4

- (iv) Complete inference is not necessarily sound. (1 mark)
- (v) $A \vee B \vee C$ is a valid sentence. (1 mark)
- (b) Given the following logical equivalence relationship.
- $$(A \wedge B \wedge C \Rightarrow D) \Leftrightarrow (\neg A \vee \neg B \vee \neg C \vee D)$$
- (i) Use rewrite rules to determine the validity of the statement. (5 marks)
- (ii) Use the truth table to determine whether the two propositions are equivalent. (5 marks)
- (c) Provide correct and concise translation in plain English for both sentences below.
- (i) $\forall x, \text{Footballer}(x) \Rightarrow \exists t, \text{busy}(x) \wedge \text{Weekend}(t)$ (2.5 marks)
- (ii) $\exists y, \forall x, \text{Person}(x) \Rightarrow \text{Love}(x,y) \wedge \text{Person}(y)$ (2.5 marks)
- (d) Given the following first order logic sentences,
- $$\begin{aligned} & \forall x, \text{Athlete}(x) \wedge \text{Fit}(x) \wedge \text{Smart}(x) \wedge \text{Lucky}(x) \Rightarrow \text{Gold_medal}(x) \\ & \forall x, \text{Train_hard}(x) \Rightarrow \text{Fit}(x) \\ & \forall x, \text{Clever}(x) \Rightarrow \text{Smart}(x) \\ & \text{Lucky(Don)} \\ & \text{Train_hard(Don)} \\ & \text{Clever(Don)} \\ & \text{Athlete(Don)} \end{aligned}$$
- using Generalized Modus Ponens, prove that “Don gets Gold Medal”. (5 marks)

4. (a) Draw decision boundary of the logistic regression.

(i) $g(z)=g(-5+x_1+x_2)$ (5 marks)

(ii) $g(z)=g(-4+x_1^2+x_2^2)$ (5 marks)

where $g(\cdot)$ is a logistic function, x_1, x_2 are input features.

(b) Figure Q4 shows a neural network with a sigmoid activation function.

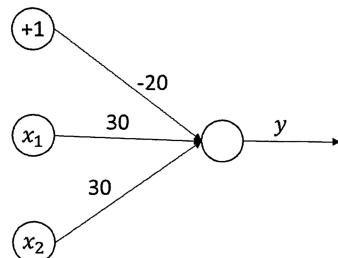


Figure Q4

(i) Derive the truth table for the output y provided that x_1 and x_2 are binary input attributes. (2.5 marks)

(ii) Determine the logical operation of the neural network. (2.5 marks)

(iii) Design a neural network to perform XNOR logical operation under binary input attributes x_1 and x_2 . Include the truth table to prove your answer. (5 marks)

Note: Question No. 4 continues on Page 6

(c) Given the following fuzzy rules,

- R1. If the temperature is very warm, the fan speed is very fast
- R2. If the temperature is warm, the fan speed is fast
- R3. If the temperature is medium, the fan speed is medium
- R4. If the temperature is cold, the fan speed is slow
- R5. If the temperature is very cold, the fan speed is very slow

draw a fuzzy neural network that implements these five fuzzy rules. State the input variables, output variables, rule antecedents, and rule consequents in your figure.

(5 marks)

CZ3005 ARTIFICIAL INTELLIGENCE

Please read the following instructions carefully:

- 1. Please do not turn over the question paper until you are told to do so. Disciplinary action may be taken against you if you do so.**
2. You are not allowed to leave the examination hall unless accompanied by an invigilator. You may raise your hand if you need to communicate with the invigilator.
3. Please write your Matriculation Number on the front of the answer book.
4. Please indicate clearly in the answer book (at the appropriate place) if you are continuing the answer to a question elsewhere in the book.