NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2022-2023

CZ3005 – ARTIFICIAL INTELLIGENCE

Nov/Dec 2022 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) Uniform-cost search is guaranteed to return an optimal solution.

   (ii) Constraint satisfaction problems can be solved by breadth first search.

   (iii) If a search algorithm is complete, it is also optimal.

   (iv) Episodic environment is often more challenging than sequential environment.

   (v) If we only change the reward function R for an MDP, the optimal policy will remain the same.

   (5 marks)

Note: Question No. 1 continues on Page 2

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(b) Answer the following questions about search in Figure Q1. S is the start state, G is the goal state. The cost of moving to a node is given by the number on the directed arc. Break any ties alphabetically. Give your answers in the form "S – A – D – G."

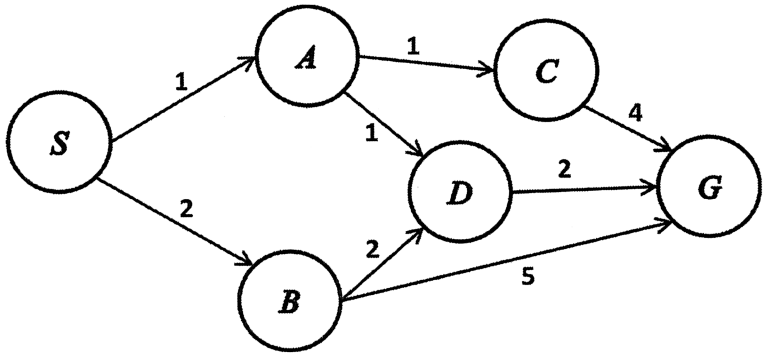

Figure Q1

(i) Apply **breadth-first search** to the graph in Figure Q1 and list the nodes that lie along the final path to the goal state.

(2 marks)

(ii) Apply **depth-first search** to the graph in Figure Q1 and list the nodes that lie along the final path to the goal state.

(2 marks)

(iii) Apply **uniform cost search** to the graph in Figure Q1 and list the nodes that lie along the final path to the goal state.

(2 marks)

(iv) If you use an admissible heuristic in which the heuristic value is not higher than the true cost, apply **A* search** to the graph in Figure Q1 and list the nodes that lie along the final path to the goal state.

(2 marks)

(c) Explain the key challenges in searching for the optimal strategy in games.

(6 marks)

(d) Explain the key idea of Monte Carlo method for reinforcement learning.

(6 marks)

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2. Imagine an unknown game which has only two states {A, B} and in each state the agent has two actions to choose from: {Up, Down}. Suppose a game agent chooses actions according to some policy π and generates the following sequence of actions and rewards in the unknown game shown in Table Q2.

Time step t	*State* s_t	*Action* a_t	*Next state* s_{t+1}	*Reward* r_{t+1}
0	A	Down	B	2
1	B	Down	B	-4
2	B	Up	B	0
3	B	Up	A	3
4	A	Up	A	1

Table Q2

(a) Unless specified otherwise, assume a discount factor $\gamma = 0.8$ and a learning rate $\alpha = 0.5$. Assume that all Q-values are initialized as 0. What are the final Q-values (i.e., Q(A, up), Q(A, Down), Q(B, up), Q(B, Down)) learned by running Q-learning with the above experience sequence?

(8 marks)

(b) What are the optimal actions at state A and B based on the learned Q values?

(4 marks)

(c) Explain the key differences between finding optimal policy in MDP and reinforcement learning.

(6 marks)

(d) Explain the key differences between value iteration and policy iteration.

(7 marks)

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3. (a) Use *truth tables* to analyse if the following logical equivalences hold.

(i) $A \Rightarrow B \Leftrightarrow A \vee (\neg B \wedge A)$

(5 marks)

(ii) $C \Leftrightarrow D \Leftrightarrow (C \Rightarrow D) \vee (D \Rightarrow C)$

(5 marks)

(b) Translate each of the following statements into a First-Order Logic sentence. Please define your own consistent symbols.

(i) "Not all birds can Fly and Swim".

(3 marks)

(ii) "There exists at least one bird which can Fly and Swim".

(3 marks)

(c) Give a concise *interpretation* of each of these following two First-Order Logic sentences in plain English.

(i) $\exists x, \exists y\ (\text{Child}(x) \wedge \text{Ice\_Cream}(y) \Rightarrow \text{Hates}(x, y))$

(2 marks)

(ii) $\exists x\ (\text{Child}(x) \Rightarrow \forall y\ (\text{Ice\_Cream}(y) \wedge \text{Hates}(x, y)))$

(2 marks)

(d) Amy, Bob, Carl, Dominic and Eva formed a study group in the library. Whenever they are studying, Amy always goes to the library if either Carl or Eva goes. But Carl will not go if Bob goes. We know that Dominic went to the library to study with Eva, and that Bob goes whenever Amy goes. Use *Propositional Logic* and *Modus Ponens* to infer logically whether Carl went to the library or not.

(5 marks)

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4. (a) Find all extensions of the following default theories T = ⟨Δ, Φ⟩:

$$T = \langle \quad \Delta = \left\{ \frac{hot(x) : \neg\, windy(x), \neg\, rainy(x)}{sunny(x)} \right\}, \quad \rangle$$
$$\Phi = \{hot(Singapore) \wedge rainy(Singapore)\}$$

(4 marks)

(b) The fuzzy variable x is described by a set of fuzzy labels over the interval [0, 24] as shown in Figure Q4.

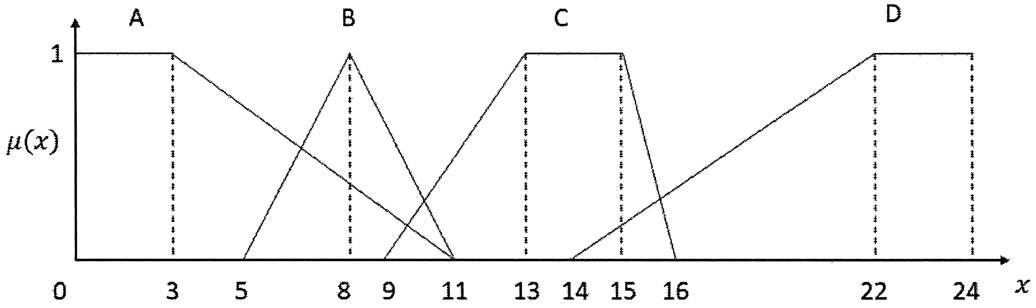

Figure Q4

(i) For each of the four fuzzy labels A, B, C and D, describe using the trapezoidal membership function in the format of *TPMF[a, b, c, d]*.

(4 marks)

(ii) State the *type of fuzzy partitioning* of the space described by these four membership functions over the given interval.

(2 marks)

Note: Question No. 4 continues on Page 6

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(c) A set of fuzzy variables *timeliness*, *quality* and *reward* are defined by the respective set of trapezoidal membership functions:

timeliness:	fuzzy term "slow" μ_{t1}:	TPMF[0, 0, 1, 3]
	fuzzy term "acceptable" μ_{t2}:	TPMF[2, 3, 6, 8]
	fuzzy term "fast" μ_{t3}:	TPMF[6.5, 8.5, 10, 10]
quality:	fuzzy term "poor" μ_{q1}:	TPMF[0, 0, 1.5, 3]
	fuzzy term "satisfactory" μ_{q2}:	TPMF[2, 3.8, 5, 7]
	fuzzy term "good" μ_{q3}:	TPMF[7, 9, 10, 10]
reward	fuzzy term "low" μ_{r1}:	TPMF[0, 0, 0, 2]
	fuzzy term "medium" μ_{r2}:	TPMF[1, 2.5, 6, 8]
	fuzzy term "high" μ_{r3}:	TPMF[6, 10, 10, 10]

(i) Draw the fuzzy partitions for each of the fuzzy variables over the domain [0, 10].

(7 marks)

(ii) State the type of fuzzy partitioning for each of the dimensions.

(2 marks)

(iii) The above fuzzy terms are used in the formulation of a fuzzy expert rule system for giving out rewards based on the timeliness and quality of work performed. Below are the three fuzzy rules:

R1. If timeliness is slow, then reward is low.
R2. If quality is satisfactory, then reward is medium.
R3. If timeliness is fast and quality is good, then reward is high.

Determine the membership for the resulting reward if the score for timeliness is 1 and the score for quality is 8. (Hint: you are not required to compute the defuzzified reward value).

(6 marks)

END OF PAPER

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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.

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