NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 2 EXAMINATION 2021-2022

CZ3005 – ARTIFICIAL INTELLIGENCE

Apr/May 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) Are the following statements True (T) or False (F)?

   (i) Breadth-first search costs more memory than iterative-deepening search.

   (ii) Any uninformed search is a special case of A^* search.

   (iii) Max player can achieve the global highest score by using Minimax algorithm.

   (iv) A pure strategy (set) is a degenerated case of a mixed strategy, where one strategy is selected with probability 1 and every other strategy with probability 0.

   (v) There is a pure strategy for the game shown in Figure Q1 (a). The value is higher when the reward is better.

(5 marks)

Note: Question No. 1 continues on Page 2

		Player 2	
		Action 1	Action 2
Player 1	Action 2	-2,-2	1,0
	Action 1	0,1	-1,-1

Figure Q1 (a)

(b) Let ***us*** be "O" player when the opponent "X" player has already placed **X** at the centre of a 3x3 Tic-Tac-Toe board, as shown in Figure Q1 (b). Please draw the game tree ***up to depth 2***, that is, "X" player's turn (the root), "O" player's turn (depth 1), and "X" player's turn (depth 2). Make sure to use symmetry to minimize the tree size.

(10 marks)

	X	

Figure Q1 (b)

(c) The heuristics of "X" player is: $3X_2+X_1-3O_2-O_1$, where X_n (or O_n) is the number of rows, columns, or diagonals with ***exactly*** *n* **X** (or *n* **O**) and no **O** (or **X**). Please re-use the heuristics for "O" player's viewpoint and use Minimax algorithm to show "O" player's optimal move.

(7 marks)

(d) When one still proposes to use the above "X" player's heuristics and apply Maximin algorithm (the opposite of Minimax) to find O's optimal move, is this a proposal valid in general? Justify your answer.

(3 marks)

2. Adaptive cruise control (ACC) is a driver-assistance agent for vehicles, which automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead. For example, if the car ahead is too close, the agent applies the brakes; if the car ahead is far away, the agent accelerates. We can model ACC as an MDP (Markov Decision Process) as shown in Figure Q2.

There are three states:

- **F**: far, where the two vehicles are distant apart, and its reward is -1.
- **C**: close, where the two vehicles are close together, and its reward is -5.
- **S**: safe, where the two vehicles are at a safe distance apart, and its reward is +1.

There are two actions:

- **a**: acceleration. For example, transition probability P (C | S, a) = 0.5.
- **b**: brake. For example, transition probability P (C | S, b) = 0.2.

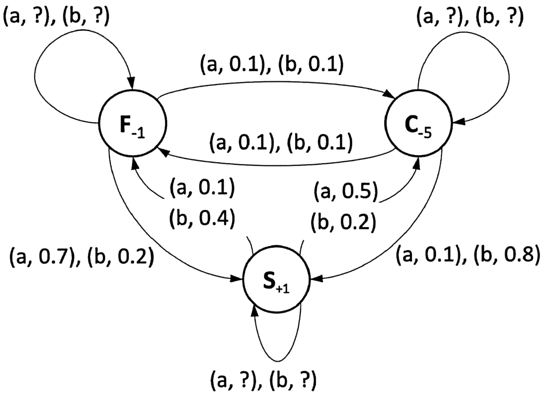

Figure Q2

(a) Complete the six unknown transition probabilities shown as "?" in Figure Q2. For example, what is P (S | S, a)?

(3 marks)

(b) Show the Q and V tables after the 1st and 2nd *synchronized* value iterations. Suppose Q and V tables are zero-initialized, reward discount γ = 0.8.

(9 marks)

Note: Question No. 2 continues on Page 4

(c) Now consider the case when the transition probability is completely unknown. Given an episode sample: (S, a)→(C, b)→(S, b)→(F, a), show the ***final*** Q table after using *asynchronized* TD update. Given that the Q table is zero-initialized, learning rate $\alpha = 0.1$ and reward discount $\gamma = 0.8$.

(6 marks)

(d) When P (C | S, a) is also unknown, we are unable to recover the transition model as we did in Q2(a). Please propose a model-based RL algorithm (in pseudo-code) that exploits both of the partial transition model and Monte Carlo training episodes. (*Hint: your answer can be a modified version of MC control*)

(7 marks)

3. (a) Are the following statements True (T) or False (F)? Justify your answers, provide an example or a short proof as necessary.

(i) If a default theory has an extension, then there are multiple extensions possible.

(ii) Expressions $A \Rightarrow (B \Rightarrow C)$ and $B \Rightarrow (A \Rightarrow C)$ are equivalent.

(iii) Modus Ponens can be represented as a constrained form of the Resolution Rule.

(iv) Resolution Rule can be implemented by a default rule.

(v) Existential and Universal qualifiers are inverse to each other. I.e., $\exists x\ \varphi(x)$ is equivalent to $\sim\forall x\ \varphi(x)$, where $\varphi(x)$ is an expression in First Order Logic with a free variable 'x'.

(10 marks)

Note: Question No. 3 continues on Page 5

(b) Consider the following expressions in English.

- Men typically have no beards, except those who are single or pilots.
- Barbers shave all men, except those who shave themselves.
- If a barber shaves a man, then that man has no beard.
- John is a man, a pilot and a barber.

(i) Convert the above expressions into a default theory.

(7 marks)

(ii) Is it credulous that John has no beard? Explain your answer in detail.

(8 marks)

4. In an Integer MaxFlow (IMF) problem, we are given a directed graph $G=(V,E)$, a source node $s \in V$, a sink node $t \in V$, and a capacity function $c:E \rightarrow N$ that associates a natural number with each edge. It is essentially a network of pipes of different sizes that connect the water source $s \in V$ to the water sink $t \in V$. IMF then defines a *legal flow* function $f:E \rightarrow N$, assigning an integer amount of water going through each pipe, to have the following properties:

- Capacity constraint: for all $e \in E$ holds $f(e) \leq c(e)$. That is, we cannot ask for more water to flow through a pipe than its size allows.

- Flow conservation: for all $v \in V$, except the source and the sink nodes, holds $\sum_{u:(u,v) \in E} f(u,v) = \sum_{u:(v,u) \in E} f(v,u)$. That is, except for the source and the target nodes, the amount of water that enters and leaves a junction of pipes is the same.

In addition, IMF defines the *value of a (legal) flow* to be $|f| = \sum_{v:(s,v) \in E} f(s,v)$, that is, the amount of water that leaves the source in a legal flow.

(a) Given an IMF instance $<G=(V,E), s, t, c:E \rightarrow N>$, formulate the problem of finding a legal flow function $f:E \rightarrow N$ as a Constraints Satisfaction Problem (CSP).

(7 marks)

Note: Question No. 4 continues on Page 6

(b) Figure Q4 depicts an instance of IMF, where numbers next to the edges denote capacity. We are tasked with finding a legal flow with the maximum possible value, while using the CSP-based description that you have developed and a search algorithm.

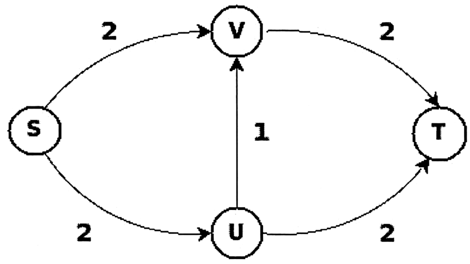

Figure Q4

(i) Describe the search tree that will be produced while solving the CSP-based IMF instance. How do its properties, such as depth and branching factor, depend on IMF instance features?

(6 marks)

(ii) Among BFS, DFS, A* and UCS, which search algorithm would you choose to apply and why?

(6 marks)

(iii) Under what circumstances will your chosen algorithm find a maximum value flow before encountering any other legal flows?

(6 marks)

END OF PAPER

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.