NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2019-2020

CZ3005 – ARTIFICIAL INTELLIGENCE

Nov/Dec 2019 Time Allowed: 2 hours

INSTRUCTIONS

1. This paper contains 4 questions and comprises 7 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).

   (i) Depth-first search has smaller space complexity as compared with breadth-first search.

   (ii) Iterative deepening search (IDS) is optimal if the cost of each action is the same.

   (iii) A* search is optimal if we use the heuristic h(n)=0 for each state n.

   (iv) Games are normally difficult to solve as it needs to deal with opponents.

   (v) It is always better to use a heuristic function with higher value h(n) for each state n.

   (5 marks)

Note: Question No. 1 continues on Page 2

(b) It has been hazy in Singapore over the last few months. From satellite image we can observe hotspots in some areas. We want to use one Unmanned Aerial Vehicle (UAV) to check the detailed situation of all the observed hotspots in the shortest time. The UAV will start from the base and would like to go back to the base after visiting all the hotspots. Define this scenario as a search problem. That is, define the states, operators, and goal test you will use.

(6 marks)

(c) Explain the concept of Constraint Propagation and how it can improve search efficiency.

(6 marks)

(d) Perform Minimax on the tree in Figure Q1. The MAX player moves first to choose the best move and then the MIN player moves. All the values are from the perspectives of the MAX player. Find the best initial move for player MAX by using minimax search. List the value of each node on the search tree.

(8 marks)

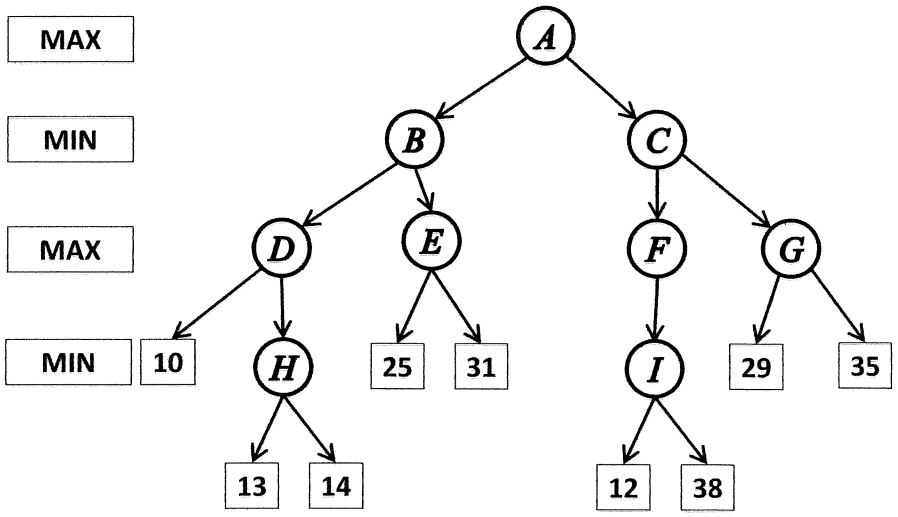

Figure Q1

2. Figure Q2 shows a graph of a search problem, where the directed arcs represent the successors of a node. The cost of moving to a node is given by the number on the arc. The value of the heuristic function *h* is shown inside each node. The start state is A and the goal is G.

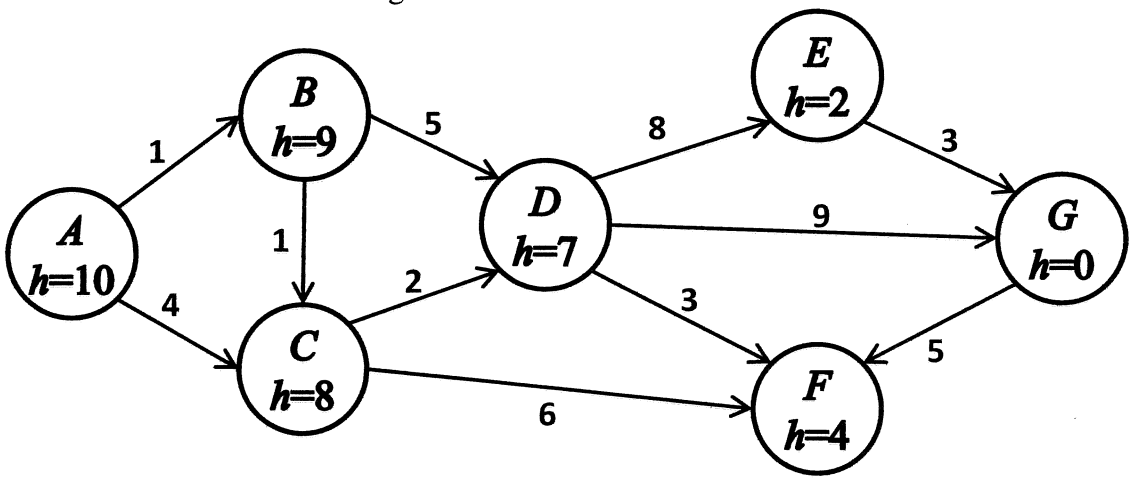

Figure Q2

For each of the following search strategies, assume that all ties are resolved in alphabetical order (i.e., the A state is expanded before the B state which is expanded before the C state, etc.). If a node has been expanded, do not expand it again.

(a) Apply **breadth-first search (BFS)** to the graph in Figure Q2: (1) list the nodes in the order they would be expanded; (2) list the nodes that lie along the final path to the goal state.

(4 marks)

(b) Apply **depth-first search (DFS)** to the graph in Figure Q2: (1) list the nodes in the order they would be expanded; (2) list the nodes that lie along the final path to the goal state.

(4 marks)

(c) Apply **uniform cost search (UCS)** to the graph in Figure Q2: (1) list the nodes and their g(n) values in the order they would be expanded; (2) list the nodes that lie along the final path to the goal state.

(5 marks)

Note: Question No. 2 continues on Page 4

(d) Apply **greedy search** to the graph in Figure Q2: (1) list the nodes and their h(n) values in the order they would be expanded; (2) list the nodes that lie along the final path to the goal state.

(5 marks)

(e) Apply **A* search** to the graph in Figure Q2: (1) list the nodes and their f(n) values in the order they would be expanded; (2) list the nodes that lie along the final path to the goal state.

(7 marks)

3. (a) Determine whether the following statements are true (**T**) or false (**F**).

(i) Logic = Representation + Inference and Representation = Syntax + Semantics.

(ii) $S \vee \neg S$ is an unsatisfiable sentence.

(iii) $S \wedge \neg S$ is a valid sentence.

(iv) Ontological commitment of proportional logic is fact.

(v) Epistemological commitment of first order logic is true or false.

(5 marks)

(b) Consider the following logical equivalence relationship.

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

(i) Using logical laws, determine the equivalence between the left hand side and right-hand side propositions.

(2 marks)

(ii) Constructing a truth table, determine whether the two propositions are equivalent.

(2 marks)

(iii) You are given with the neural network (NN) in Figure Q3.

Note: Question No. 3 continues on Page 5

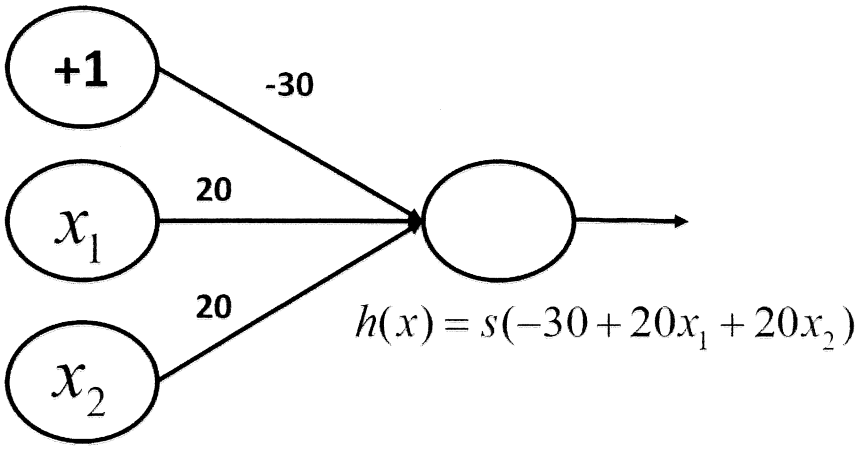

Figure Q3

Analyze the functionality of NN in Figure Q3 by deriving its possible outputs under binary inputs x_1, x_2 and determine its binary operation. Note that the sigmoid activation function is used here.

(3 marks)

(iv) $N(x;\mu,\sigma)$ is a Gaussian membership function with the center μ and width σ. Suppose that $\mu = 5, \sigma = 1$, draw the membership function $N(x;\mu,\sigma)$ assuming that x is a real variable in the range of [0,10].

(3 marks)

(c) You are given with the following propositional logic sentences.

- If Andy works hard and Andy is smart, Andy passes the subject.
- Andy works hard.
- Andy is smart.

(i) Using modus ponens, prove that **Andy passes the subject.**

(5 marks)

(ii) Using resolution by refutation, prove that **Andy passes the subject.**

(5 marks)

4. (a) You are given with Fuzzy Neural Network (FNN) diagram in Figure Q4.

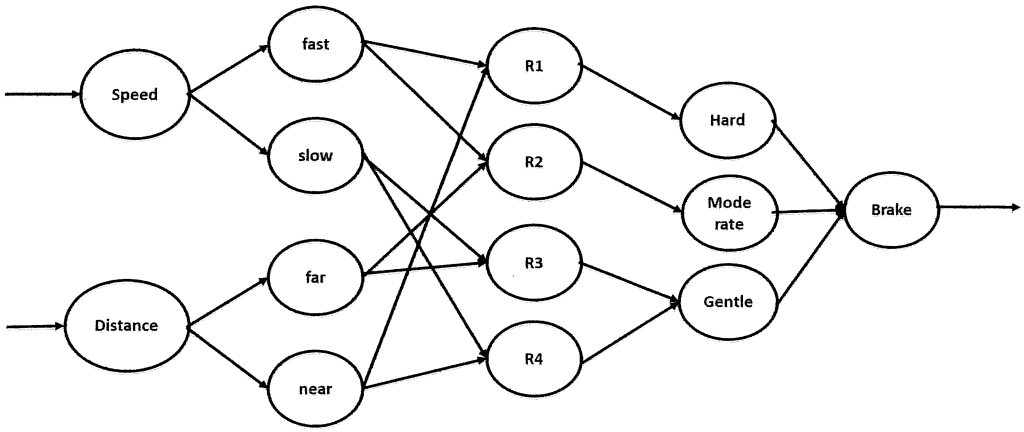

Figure Q4

Write fuzzy linguistic rules of the FNN diagram given in Figure Q4.

(5 marks)

(b) Design Neural Networks (NNs) that function as **NOT** operator under binary input X. Your answer must include NN's structures, its weights and must show truth tables that support the functionality of your NN.

(5 marks)

(c) Translate the following First Order Logic (FOL) sentences to natural English.

(i) $\forall x, y, Teacher(x, y) \wedge Student(y, x) \Rightarrow Love(x, y)$

(2 marks)

(ii) $\forall x, Student(x) \wedge Lazy(x) \Rightarrow fails(x)$

(2 marks)

(d) You are given with the following first order logic sentences below.

Note: Question No. 4 continues on Page 7

- $\forall x, y, \neg Payticket(x, y) \Rightarrow Home(x)$
- $\forall x, y, \neg Payticket(x, y) \Rightarrow Poor(y)$
- $\forall x, y, Unhappy(x) \Rightarrow \neg Payticket(x, y)$
- $\forall x, y, Fans(x, y) \wedge Lose(y) \Rightarrow Unhappy(x)$
- $Lose(Chelsea)$
- $Fans(John, Chelsea)$

(i) Using generalized modus ponens concept, prove that "John is at home".

(5 marks)

(ii) Using generalized modus ponens concept, prove that "Chelsea is poor".

(5 marks)

(iii) Describe the advantage of resolution by refutation over the resolution inference rule.

(1 mark)

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.