NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2016-2017

CZ3005 – ARTIFICIAL INTELLIGENCE

Nov/Dec 2016 Time Allowed: 2 hours

INSTRUCTIONS

1. This paper contains 4 questions and comprises 5 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) Iterative deepening search (IDS) will always find a solution if there is one.

(ii) The runtime of IDS is higher than the runtime of breadth-first search (BFS).

(iii) A* search is guaranteed to expand no more nodes than uniform-cost search (UCS).

(iv) The environment of game Go is dynamic.

(v) In a problem formulation, there might be multiple goal states with different shortest paths.

(5 marks)

Note: Question No. 1 continues on Page 2

(b) Given two arbitrary admissible heuristics, *h1* and *h2*, which composite heuristic is better to use, max(*h1*, *h2*), (*h1* + *h2*)/2, or min(*h1*, *h2*)? Explain briefly why.

(5 marks)

(c) Consider solving the 4-queens problem as a constraint satisfaction problem. That is, place 4 queens on a 4 × 4 board such that no queen is in the same row, column or diagonal as any other queen. One way to formulate this problem is to have a variable for each queen, and binary constraints between each pair of queens indicating that they cannot be in the same row, column or diagonal. Assuming the i^{th} queen is put somewhere in the i^{th} column, then the possible values in the domain for each variable are the row numbers in which it could be placed. Say we initially assign queen Q1 the unique value 3, meaning Q1 is placed in column 1 and row 3. Apply constraint propagation and give the remaining candidate values for the variables Q2, Q3 and Q4.

(6 marks)

(d) This problem looks at playing the game tic-tac-toe. Assume that X is the MAX player. Let the utility of a win for X be 10, a loss for X be -10, and a draw be 0.

Figure Q1 shows the game board where it is X's turn to play next. Show the entire game tree. Mark the utilities of each terminal state and use the minimax algorithm to calculate the utilities of each nonterminal state and the optimal move.

X	O	X
O		O
	X	

Figure Q1

(9 marks)

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 S and the goal is G.

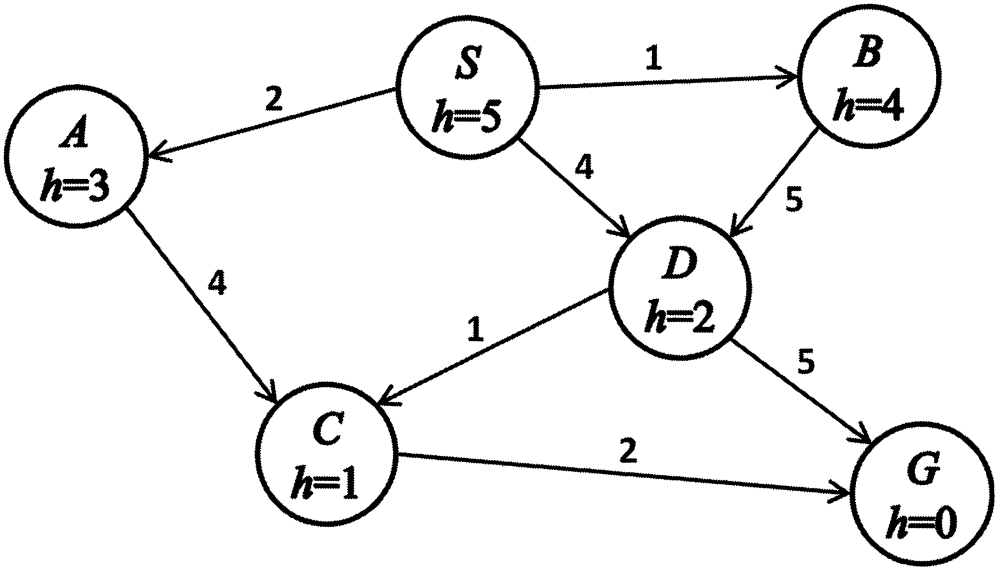

Figure Q2

For each of the following search strategies, state the order in which states are expanded (i.e., when they are removed from the frontier), as well as the final path returned when the search is finished. 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 add the node to the frontier again.

(a) Apply **breadth-first search** 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.

(3 marks)

(b) Apply **depth-first search** 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.

(3 marks)

Note: Question No. 2 continues on Page 4

(c) Apply **uniform cost search** 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. If you find a path to a node already on the frontier, you update its cost (using the lower value) instead of adding another copy of that node to the frontier.

(6 marks)

(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. If you find a path to a node already on the frontier, you update its cost (using the lower value) instead of adding another copy of that node to the frontier.

(6 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. If you find a path to a node already on the frontier, you update its cost (using the lower value) instead of adding another copy of that node to the frontier.

(7 marks)

3. (a) Decide whether the following logical equivalences hold.

(i) Verify your decision using truth tables

$$P \Rightarrow Q \Leftrightarrow \neg Q \Rightarrow \neg P$$

(3 marks)

(ii) Verify your decision using the equivalence rules

$$\neg (P \Leftrightarrow Q) \Leftrightarrow (P \Leftrightarrow \neg Q)$$

(6 marks)

(b) Consider the following knowledge base KB:

$P \vee Q$

$P \Rightarrow R$

$Q \Rightarrow S$

Prove

$KB \models S \vee R$

(6 marks)

Note: Question No. 3 continues on Page 5

(c) If A is working hard, B or C will be happy. If B is happy, A will not work hard. If D is happy, C will not be happy.

(i) Translate the above knowledge into Propositional Logic.

(4 marks)

(ii) Prove that if A is working hard, D is not happy.

(6 marks)

4. (a) Translate the following statements into a First Order Logic sentence.

There is only one Singapore.

(3 marks)

(b) Prove $\exists x\ (P(x) \Rightarrow Q(x)) = \forall x\ P(x) \Rightarrow \exists x\ Q(x)$.

(6 marks)

(c) Students in NTU are either undergraduate students or postgraduate students. Some are talents. John is not a postgraduate student but he is a talent. So if John is a student of NTU, he must be an undergraduate student.

(i) Translate the above statements first into First Order Logic sentences and then into CNF (conjunctive normal form).

(8 marks)

(ii) Show a resolution refutation proof that John is an undergraduate student.

(8 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.