CSIS, BITS Pilani K. K. Birla Goa Campus

Artificial Intelligence (CS F407)

Comprehensive Exam (03/12/2019)
Total Marks: 40
Time Limit: 3 Hours

This question paper contains **five** questions. All questions are compulsory.

Please start the answer to each question on a new page. Answer all parts of a question in the same place.

Question 1 (6 marks)

Mark each of the following six parts ((a) to (f)) as either **True** or **False**. There is no negative marking.

(a) (1 mark) We are given a finite state space graph, where the problem is to find the shortest path from the initial to a goal state. If the step costs are positive, then iterative deepening search will be optimal. (True/False)

(b) (1 mark) Suppose we use A^* search to find the shortest path between the initial and the goal states in a finite state space graph. Let all the step costs be positive. Also, let the value given by the heuristic function $h(n)$ be zero for all the nodes. In this case, A^* search will be both optimal and complete. (True/False)

(c) (1 mark) We have to find the global maximum of an objective function for a state space. It is given that the steepest-ascent hill-climbing gets stuck at a plateau 80% of the times. If we use random-restart (steepest-ascent) hill climbing, then the expected number of restarts required will be approximately two. (True/False)

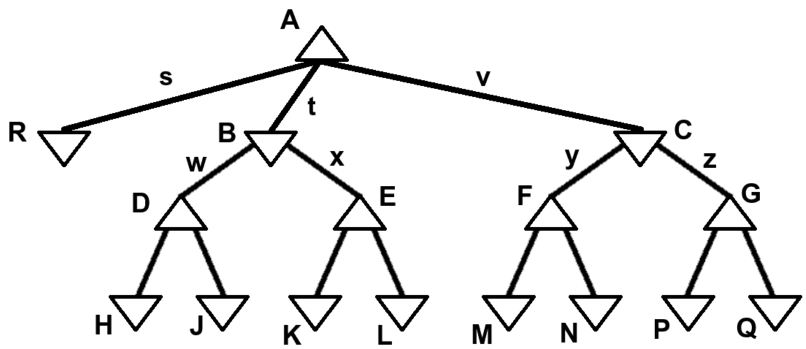
(d) (1 mark) Horizon effect can occur in a two-player, turn-taking, fully observable, zero-sum game (e.g. chess). Horizon effect occurs because we may not know the best evaluation function for non-terminal states. (True/False)

(e) (1 mark) Frame problem occurs because in propositional logic we cannot represent relations between objects. (True/False)

(f) (1 mark) Suppose we have a knowledge base (KB) that contains the following two first-order logic sentences: $Spouse(Jim, Laura)$, $Jim \neq George$. If we assume the standard first-order logic semantics, then the knowledge base (KB) entails $\neg Spouse(George, Laura)$. (True/False)

Question 2 (8 marks)

The figure below shows a game tree for a two-player zero-sum game. The utilities for the terminal (leaf) nodes are shown in the table. The nodes in the game tree are labeled by A, R, B, C, D, E, F, G, H, J, K, L, M, N, P and Q. The actions in the game tree are labeled by s, t, v, w, x, y and z. Let $\triangle$ denote a MAX node and $\bigtriangledown$ denote a MIN node. Assume that the algorithms always explore the child nodes from left to right.



Node	R	H	J	K	L	M	N	P	Q
Utility	7	7	8	9	1	3	2	9	10

(a) (1 mark) Find the MINIMAX value for node A.

(b) (2 marks) Suppose player at every node takes minimax decision. What action will the player at node A choose? Why is node A player's decision optimal?

(c) (1 mark) Why is alpha-beta pruning performed? Give a very brief answer.

(d) (2 marks) Suppose we perform alpha-beta search for finding the minimax values. What will be the alpha value at node B and node C when they are explored using alpha-beta search? What will be the beta value at node E and node F when they are explored using alpha-beta search?

(e) (2 marks) Some nodes in the tree will be completely ignored (i.e. will not be explored) by alpha-beta search. Identify these nodes in the given game tree.

Question 3 (8 marks)

Consider the modified Sudoku puzzle shown below. The puzzle is to fill each of the 12 squares with digits from 1 to 4 such that no digit appears twice in any row or column. Also, no digit should appear twice in the top-left, top-right and bottom-left 2 × 2 box. The rows are labeled from A to D, and the columns are labeled from 1 to 4. These labels can be used to uniquely identify all the squares in the puzzle.

It is given that the squares $B2$ and $D2$ must contain 4 and 3 respectively. The puzzle and one possible solution is shown below.

	1	2	3	4
A				
B		4		
C				
D		3		

(a) Puzzle

	1	2	3	4
A	2	1	3	4
B	3	4	1	2
C	4	2		
D	1	3		

(b) One possible solution

The above puzzle can be expressed as a constraint satisfaction problem as follows. Let the variables $A1$ to $A4$ refer to the squares on the top row. Let $B1$ to $B4$ refer to the squares on the second row, and so on. Let the domain of all the variables be $D_i = \{1, 2, 3, 4\}$. The variables must satisfy the following nine constraints: Alldiff($A1, A2, A3, A4$), Alldiff($B1, B2, B3, B4$), Alldiff($A1, B1, C1, D1$), Alldiff($A2, B2, C2, D2$), Alldiff($A1, A2, B1, B2$), Alldiff($A3, A4, B3, B4$), Alldiff($C1, C2, D1, D2$), $B2 = 4$ and $D2 = 3$.

The last two constraints are unary constraints that ensure that the squares $B2$ and $D2$ are assigned appropriate values. The Alldiff(...) constraint is satisfied only when all the variables in the constraint have different values. Each Alldiff(...) constraint can be thought of as multiple $\neq$ binary constraints.

To find a solution we first achieve node consistency and arc consistency, and then we use the Backtracking-Search algorithm to find a solution.

(a) (2 marks) What will be the domains of variables $A3$ and $D1$ after node consistency and arc consistency are achieved?

(b) (1 mark) As mentioned above, we use the Backtracking-Search algorithm after node consistency and arc consistency are achieved. What will be the number of leaf nodes in the search tree (i.e. the number of possible unique assignments to the variables after node consistency and arc consistency are achieved)?

(c) (1 mark) Why **minimum-remaining-values** heuristic (for selecting an unassigned variable) is an effective strategy in Backtracking search? Give a very brief answer.

(d) (1 mark) Suppose that our Backtracking algorithm uses the **minimum-remaining-values** heuristic, and the **degree heuristic** is used as a tie-breaker. Which unassigned variable will be selected by the Backtracking-Search at level-0 (root node) of the search tree? (Assume node consistency and arc consistency have been achieved.)

(e) ($1\frac{1}{2}$ marks) *Forward checking* and *maintaining arc consistency* are techniques used by the Backtracking-Search to reduce the domains of unassigned variables after a variable has been assigned a value. Suppose the Backtracking-Search algorithm assigns a value of 2 to the variable selected in part (d) above. What will be the new domains of $A3$ and $D1$ if only the forward checking technique is used. (Marks will be awarded only if the answer to part (d) above is correct.)

(f) ($1\frac{1}{2}$ marks) Suppose the Backtracking-Search algorithm assigns a value of 2 to the variable selected in part (d) above. What will be the updated domains of $A3$ and $D1$ if maintaining arc consistency technique is used. (Marks will be awarded only if the answer to part (d) above is correct.)

Question 4 (9 marks)

Consider the following three sentences:

If there is a *party* (P), then there is *food* (F) and *drinks* (D).

If there is no *party*, then either there is *food* or there are *games* (G) or both.

There are no *games*.

(a) (2 marks) Construct a knowledge base (KB) using propositional logic, that represents the three English sentences mentioned above. Use the symbols P, F, D and G to construct the knowledge base.

(b) (2 marks) Use model checking inference procedure to find all the models in which the knowledge base (KB) found in part (a) is true. From the models can we conclude that there is a party (i.e. Does $KB \models P$)? Justify your answer.

(c) (2 marks) Suppose instead of model checking we use the DPLL algorithm to check whether knowledge base entails party (i.e $KB \models P$?). Find the sentence α (in Conjunctive Normal Form) that the DPLL algorithm should check for satisfiability to determine whether $KB \models P$.

(d) (3 marks) The DPLL algorithm makes all the pure symbols true and then it makes all the unit clauses true.

(i) Find the pure symbols and the atomic clauses in the sentence α found in part (c) above.

(ii) Find the (final) variable assignments that the DPLL algorithm will make while checking whether α is satisfiable.

(Marks will be awarded for part (d) only if the answer to part (c) is correct.)

Question 5 (9 marks)

Consider the following sentences:

A. Every country owns a torpedo.

B. Every country that owns a missile is not loved by some person.

C. Nono is a country.

D. Every person loves Nono.

(a) (3 marks) Use predicate symbols $Country$, $Torpedo$, $Missile$, $Owns$, $Loves$ and $Person$ to construct a first-order logic knowledge base (KB) that represents the English sentences listed above.

(b) (3 marks) Convert the sentences in the knowledge base (KB) found in part (a) to equivalent CNF form. Standardize apart the variables and perform skolemization where necessary. Your final answer should list all the clauses found. Intermediate steps must also be shown.

(c) (3 marks) Let α be the first-order-logic sentence corresponding to *"Nono does not own any missile"*. Use resolution algorithm to check whether $KB \models \alpha$? Draw a diagram that shows clauses that will be resolved in each step, and the resolvent clause derived in each step. Assume that the resolution algorithm continues to apply the resolution rule until either fixed point is reached or an empty clause is derived. (Marks for part (c) will be awarded only if the clauses found in part (b) are correct.)