UNIVERSITY OF LONDON

BSc EXAMINATION 2022

For Internal Students of
Royal Holloway

DO NOT TURN OVER UNTIL TOLD TO BEGIN

CS2910: Artificial Intelligence
CS2910R: Artificial Intelligence – for FIRSTSIT/RESIT CANDIDATES

Time Allowed: **TWO hours**

Please answer **ALL** questions

1. (a) Consider the graph in Figure 1. Show the order of nodes visited for breadth-first search and depth-first search.

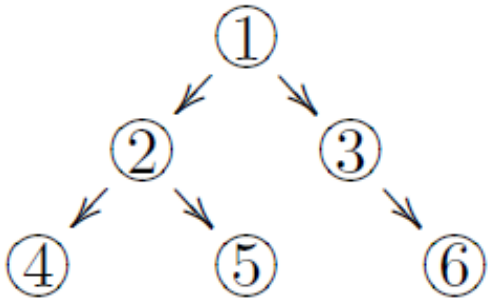

Figure 1: Graph

[5 marks]

(b) Consider the graph in Figure 2. The initial state is 0. Run the depth-first search algorithm on this problem. Draw the search graph and annotate the nodes with the order in which states are selected for expansion.

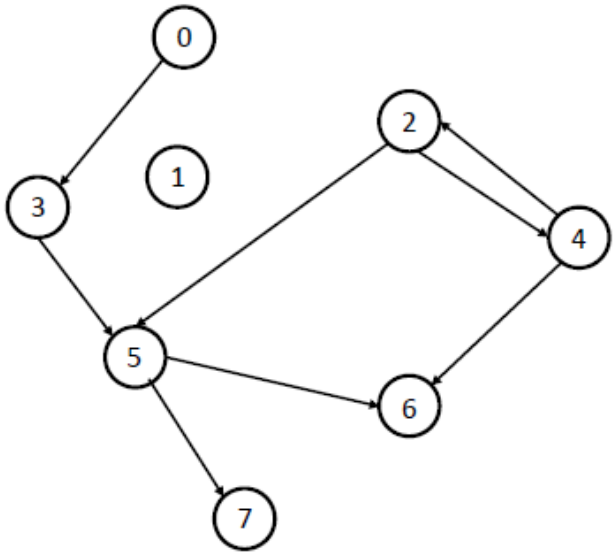

Figure 2: Graph for depth-first search

[5 marks]

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(c) What are the time and space complexities of the breadth-first search and depth-first search algorithms? [5 marks]

(d) Describe the terms “complete” and “optimal” with regards to evaluating search strategies. [4 marks]

(e) Is either depth-first search or breadth-first search complete or optimal? Justify your answer. [6 marks]

2. This question is about adversarial search.

   (a) What is adversarial search? [4 marks]

   (b) Consider the game tree of Figure 3.

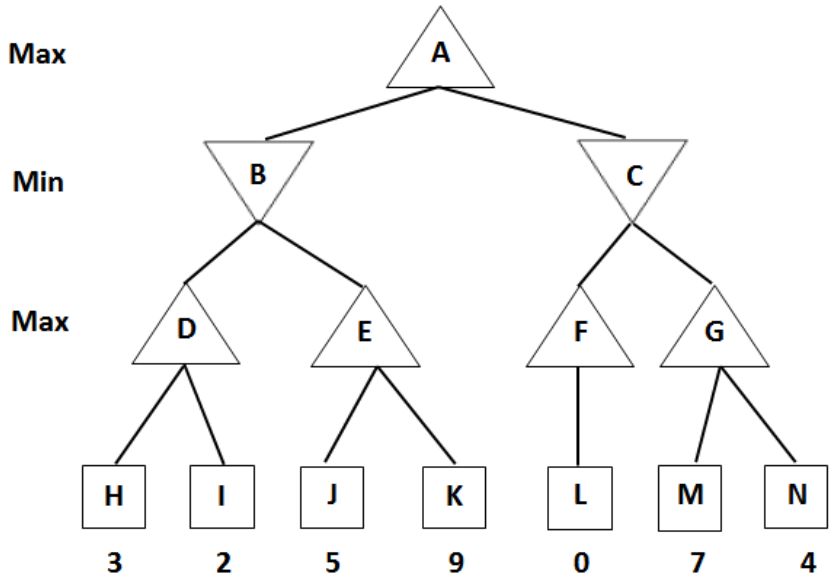

Figure 3: A two-player game tree. $\triangle$ denotes the MAX node, while ∇ denotes the MIN node.

Redraw the above tree showing the values of non-leaf nodes after you apply the MINIMAX algorithm. Using these MINIMAX values, explain the solution of the search. [11 marks]

(c) Perform Alpha-Beta pruning algorithm on the tree. Annotate all internal nodes (that are not pruned) with the value that will be propagated to the parent node. Mark which edges will be pruned. How many leaf nodes are pruned? [10 marks]

3. This question is about unification, knowledge representation and forward reasoning computation.

   (a) Following logic programming conventions for variables, predicates and function symbols, give the most general unifier for each pair of atomic sentences, if it exists. Justify your answer if no unifier exists.

      i. `advisorOf(Y, pm(Z))` and `advisorOf(general(Z), pm(uk))` [1 mark]
      ii. `borrows(X, Y, henry)` and `borrows(father(Z), 10, Y)` [1 mark]
      iii. `f(g(10), f(10), Y)` and `f(f(10), g(10), X)` [1 mark]
      iv. `g(f(X), f(g(X)))` and `g(f(h(Z)), f(g(h(Y))))` [1 mark]
      v. `define(V, V, g(g(a)))` and `define(W, g(Z), g(W))`. [1 mark]

   (b) Represent the following statements as definite clauses:

      i. Sorcerers, wizards, and witches know magic. [3 marks]
      ii. James is a wizard. [1 marks]
      iii. James and Lily are Harry's parents. [1 marks]
      iv. The child of a wizard is a wizard. [3 marks]
      v. Voldemort is James's nemesis. [1 marks]
      vi. The nemesis of a wizard is also the nemesis of the wizard's children. [3 marks]

   (c) Use forward reasoning on the definite clauses you specified in Question 3b to show that Harry is a wizard and Voldemort is his nemesis. Justify your answer. [6 marks]

4. This question is about mechanisms supporting logical inference, resolution and backward reasoning. Upper case letters denote constants, while lower case letters denote variables.

   (a) Recall that inference procedures are used to implement entailment.

      i. Given a goal and a knowledge base, formally explain what it means for an inference procedure to be sound. [3 marks]

      ii. Contrast soundness with completeness by explaining the potential shortcomings of an inference procedure that is sound but not complete. [4 marks]

   (b) The resolution inference rule combines two clauses to make a new one.

      i. Give the propositional version of the resolution inference rule. [1 marks]

      ii. Give the first order logic version of the resolution inference rule. [2 marks]

      iii. Explain the key difference(s) between these two versions of the rule. [2 marks]

   (c) Consider the logic program $\mathcal{P}$ below.

$$
\begin{aligned}
&at\_risk(x) \leftarrow expensive(x), parking(x, y), unsafe(y)\\
&expensive(x) \leftarrow race\_bike(x)\\
&parking(Trek, Lamp\_post)\\
&parking(Cervelo, Garage)\\
&unsafe(Lamp\_post)\\
&race\_bike(Cervelo)\\
&race\_bike(Trek)\\
&commute\_bike(Carrera)
\end{aligned}
$$

   Determine whether forward chaining or backward chaining is best suited to identify which bicycles are *at risk* of being stolen (if any).

   Use your chosen approach on program $\mathcal{P}$ to determine which bicycles are at risk. Your answer must show step-by-step how your conclusions were reached (including your substitutions). [10 marks]

END