UNIVERSITY OF LONDON

GOLDSMITHS COLLEGE

Department of Computing

B. Sc. Examination 2017

IS53024A
Artificial Intelligence

Duration: 2 hours 15 minutes

Date and time:

This paper is in two parts: part A and part B. You should answer ALL questions from part A and TWO questions from part B. Part A carries 40 marks, and each question from part B carries 30 marks. The marks for each part of a question are indicated at the end of the part in [.] brackets.

There are 100 marks available on this paper.

No calculators should be used.

THIS PAPER MUST NOT BE REMOVED FROM THE EXAMINATION ROOM

Part A

Question 1

(a) Write, as pseudocode, *tree search*. [5]

(b) What are the attributes of a well-defined problem? [5]

(c) Define [5]

   i. time complexity
   ii. space complexity
   iii. state expansion
   iv. the search frontier
   v. the explored set

(d) What is local search? What are its advantages? [5]

Question 2

(a) Interpret the operation of a rule-based system on the given propositional rules and facts. Consider, first, the forward chaining algorithm and, second, the backward chaining algorithm. Prove in both cases that the goal (C) is true, assuming the following rules and facts in the order in which they are given.

```
(Rule 1 (IF ( D ) and ( E )) (THEN ( G )))
(Rule 2 (IF ( D ) and ( F )) (THEN ( A )))
(Rule 3 (IF ( B ) (THEN ( F )))
(Rule 4 (IF ( A ) (THEN ( C )))
(Fact 1 ( D ))
(Fact 2 ( B ))
```

i) Give the forward sequence of rule firings and explain how the rules and the facts have been applied. [10]

ii) Give the backward sequence of rule firings and explain how the rules and the facts have been applied. [10]

Part B

Question 3

This question is about a two player game called Matching Pennies. Each player contributes a penny. The game is played by choosing heads or tails and simultaneously revealing the choice. Player A wins and collects both pennies if they both show heads or both show tails. Otherwise, player B wins and collects the pennies.

(a) Write down the Matching Pennies pay-off matrix. [5]

(b) Does Matching Pennies have a pure strategy Nash equilibrium? Justify your answer. [5]

(c) What is a mixed strategy Nash equilibrium? [5]

(d) Suppose that the game proceeds in turns and that A starts by playing a mixed strategy $[p : heads; (1 - p) : tails]$. B knows p and responds with a pure strategy.

Find, using the minimax algorithm, the payoff U_{AB} for this game, and state A's preferred value for p.

You should assume that A is the maximiser and that B is the minimiser. [6]

(e) Now, suppose again that the game proceeds in turns, but that B starts by playing a mixed strategy $[q : heads; (1 - q) : tails]$. A knows q and responds with a pure strategy.

Find, using the minimax algorithm, the payoff U_{BA}, and state B's preferred value for q.

Once more, assume that A is the maximiser and that B is the minimiser. [6]

(f) Hence find the true utility, U, and the mixed strategy equilibrium in the case when players perform their moves simultaneously. [3]

Question 4

(a) Consider the task of automatic inference of family relationships using a rule-based system. Assume that family relationships are described by the following rules and facts:

```
(Rule 1  (IF   (sibling ?y ?w) (gender ?w Female))
         (THEN (sister ?y ?w)))

(Rule 2  (IF   (gender ?z Female) (parent ?x ?y) (sister ?y ?z))
         (THEN (aunt ?x ?z)))

(Rule 3  (IF   (parent ?x ?y) (child ?y ?z))
         (THEN (sibling ?x ?z)))
```

Assume that the initial situation is described with the following facts:
(Fact 1 (child Diana Sarah))
(Fact 2 (child John Sarah))
(Fact 3 (parent William Ana))
(Fact 4 (parent Charles John))
(Fact 5 (parent William Charles))
(Fact 6 (gender Sarah Female))
(Fact 7 (child John Charles))

i) Give the sequence in which the rules are selected. [12]

ii) When matching templates give the corresponding variable bindings. [8]

iii) Explain how backtracking is performed during the search process. [6]

iv) Give the sequence in which the rules fire. [4]

Question 5

(a) Consider the general hill climbing search algorithm: [5]

Algorithm 1

```
procedure HillClimbing
    /* Search space X, objective function f */
    current ← a random state in X
    loop
        neighbour ← a highest-valued successor of current
        if f(neighbour) ≤ f(current) then
            return current
        current ← neighbour
```

It is claimed that the algorithm can get stuck in loops (repeated states). Is this claim correct? Explain your answer.

(b) Adjust Algorithm 1 so that moves to a downhill neighbour, as well as an uphill neighbour, are possible. [5]

(c) Adjust your answer to part (b) so that downhill moves become increasingly unlikely. [5]

(d) Interpret the performance of the candidate elimination learning algorithm. Let a concept description language with 4 attributes be given. Assume that these attributes can take the following values:

```
  a1          a2         a3          a4
 ----      ---------    ----     ---------
|    |    |    |    |   |    |   |    |    |
a    b    c    d    e   f    g   h    i    j
```

Illustrate symbolic learning with the candidate elimination algorithm using the following positive and negative training examples:

```
1. ( b d g i ) +)
2. ( b c f j ) -)
3. ( a d g j ) +)
4. ( b d f j ) -)
5. ( b c g i ) -)
```

i) Give the modifications of the boundary sets after the first example. [3]

ii) Give the modifications of the boundary sets after the second example. [3]

iii) Give the modifications of the boundary sets after the third example. [3]

iv) Give the modifications of the boundary sets after the fourth example. [3]

v) Give the modifications of the boundary sets after the fifth example. [3]