**UNIVERSITY OF LONDON**

**GOLDSMITHS COLLEGE**

**B. Sc. Examination 2014**

## Computing

## IS53024A Artificial Intelligence

**Duration: 2 hours and 15 minutes**

**Date and time:**

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*There are five questions in this paper. You should answer no more than three questions. Full marks will be awarded for complete answers to a total of three questions. Each question carries 25 marks. The marks for each part of a question are indicated at the end of the part in* [.] *brackets.*

*There are 75 marks available on this paper.*

*Electronic calculators must not be programmed prior to the examination. Calculators which display graphics, text or algebraic equations are not allowed.*

**THIS PAPER MUST NOT BE REMOVED FROM THE EXAMINATION ROOM**

**Question 1**

(a) What is a *learning agent*? Draw a structural diagram of the learning agent to demonstrate its main components and their interaction. Explain the characteristics of the components. [10]

(b) Consider a rule-based system for goal-directed reasoning. Show how it will apply the backward chaining algorithm to prove the goal ( I ). Use the following rules and facts in the order in which they are given. [15]

```
(RULE 1 (IF ( N ) and ( V )) (THEN ( I )))
(RULE 2 (IF ( R ) (THEN ( N )))
(RULE 3 (IF ( B ) (THEN ( A )))
(RULE 4 (IF ( H ) (THEN ( A )))
(RULE 5 (IF ( T ) (THEN ( F )))
(RULE 6 (IF ( F ) and ( A ) and ( C )) (THEN ( V )))
(FACT 1 ( R ))
(FACT 2 ( H ))
(FACT 3 ( T ))
(FACT 4 ( C ))
```

**Question 2**

Consider the pseudo 8-puzzle problem. A $3 \times 3$ board with eight numbers and a blank space (□). A number adjacent to the blank space can slide into the space horizontally or vertically. Assume the 8 numbers are placed as $\begin{matrix} \square & 1 & 2 \\ 4 & 5 & 3 \\ 7 & 8 & 6 \end{matrix}$ initially, and after a number of legal moves, we aim to reach $\begin{matrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & \square \end{matrix}$.

(a) Write down, as specifically as possible, the *problem definition* and the *task environment* for the instance in terms of the (i) state, (ii) action, (iii) transition model, (iv) goal test and (v) path cost. Provide an example for each of the terms to show your understanding. [10]

(b) Draw a series of diagrams to show how a search tree may be expanded step by step applying the Breadth-First Search (Graph-Search version) algorithm for the problem instance. Highlight the characteristics of the search algorithm and show all your work. [4]

(c) Demonstrate how the Greedy Best-First search algorithm works. Trace step by step the expansion of the search tree, the evaluation and choice made on each state in execution of the algorithm. Use the number of misplaced numbers as the heuristic. Highlight the characteristics of the algorithm and show all your work. [5]

(d) Demonstrate how the A* search algorithm works. Trace step by step the expansion of the search tree, the evaluation and choice made on each state visited in execution of the algorithm. Highlight the characteristics of the algorithm and show all your work. Assume $g(n)$ is the depth of node $n$ in the search graph. [6]

**Question 3**

Consider a simple game for two players $A$ and $B$. Initially, player $A$ is at location i, and player $B$ is at location iv, as shown in the figure below.

| i | ii | iii | iv |
|---|---|---|---|
| $A$ | | | $B$ |

Player $A$ moves first. Players $A$ and $B$ then move alternately, one at a time. A player must move his piece to an open adjacent space in either left or right direction (Passes are not permitted). If the opponent occupies an adjacent space, then a player may jump over the opponent to the next open space. The game ends when one player reaches the opposite end of the array. That is, if $A$ reaches location iv first, then the score of the game to player $A$ is +1. If $B$ reaches location i first, then the score of the game to player $A$ is -1.

(a) Draw a game tree for the game, and highlight the winning state and redundant state using round brackets "()". [8]

(b) Draw a state graph for the game. [6]

(c) Conduct a graph search on the state graph derived in part (b) using the GRAPH-SEARCH algorithm. Demonstrate the separation property of the algorithm with the aid of a diagram. [5]

(d) Explain and demonstrate how the MinMax algorithm can be applied to find the optimal solution. Comment on the fairness of the game. [6]

**Question 4**

(a) Explain briefly how does the interpreter of a rule-based system continue after choosing a rule and performing the actions suggested in the chosen rule? [5]

(b) Demonstrate the performance of the backward chaining algorithm using the following rules with variables for planning in the blocks-world:

```
//stack onto
(RULE 1  (IF   (clear ?x) and (clear ?y) and (ontable ?x))
         (THEN (DELETE (clear ?y))
               (ADD (on ?x ?y)))
//unstack
(RULE 2  (IF   (on ?x ?y) and (clear ?x))
         (THEN (DELETE (on ?x ?y))
               (ADD (clear ?y))
               (ADD (ontable ?x)))
```

Assume that the initial configuration is defined with the following facts:

```
(ontable C)(ontable A)(ontable D)(clear B)(clear C)(clear D)(on B A)
```

Prove sequentially the following goals: (on C A), (on B D) and show the variable bindings at each step of the algorithm. [20]

**Question 5**

(a) Define the inductive concept learning task, and explain what is given and what should be determined. [5]

(b) Describe which concepts are included in the boundary sets maintained by the version space learning approach. [8]

(c) Consider a concept description language with five attributes predefined as follows:

```
   a1        a2         a3         a4    a5
 -------   -------   -----------   ---   ---
|  |  |  |  |  |  |  |  |  |  |  |  |  |
e  c  b  m  p  u  r  n  i  q  x  v  z  w
```

Perform version space learning using the following positive and negative training examples:

```
1.  ( e m r x z ) +)
2.  ( c m n x z ) +)
3.  ( c p i v w ) -)
4.  ( b u q x z ) +)
```

Show how the candidate elimination algorithm changes the boundary sets after processing each example. [12]