UNIVERSITY OF LONDON

GOLDSMITHS COLLEGE

B. Sc. Examination 2004

COMPUTING AND INFORMATION SYSTEMS

IS53001A (CIS310) Artificial Intelligence

Duration: 2 **hours** 15 **minutes**

Date and time:

There are FIVE questions on this paper.

Do not attempt more than THREE questions.

Full marks will be awarded for complete answers to THREE questions.

There are a total of 75 marks available on this paper.

Electronic calculators may be used. The make and model should be specified on the script. The calculator must not be programmed prior to the examination. Calculators which display graphics, text or algebraic equations are not allowed.

THIS EXAMINATION PAPER MUST NOT BE REMOVED FROM THE EXAMINATION ROOM

Question 1 Search and Problem Solving

(a) (i) How can we measure the *complexity* of search algorithms?

(ii) Describe in your own words the algorithms for greedy search and uniform-cost search. Compare the algorithms in terms of completeness, optimality and time complexity.

[7]

(b) The 8-puzzle consists of a 3 x 3 grid with 8 numbered tiles and one blank space into which an adjacent tile may be moved. Tiles may be moved vertically or horizontally but not diagonally.

(i) Briefly explain how we can specify states of the puzzle and the legal operations which can be used to solve the 8-puzzle efficiently as a search problem.

(ii) What is the minimum number of tile moves needed to get from the start state shown below to the goal state? Show the search tree generated by *breadth-first search*,indicating which operation applies at each branch.

Start State

2	8	3
1	•	4
7	6	5

Goal State

1	2	3
8	•	4
7	6	5

[12]

(c) Why are *heuristics* important for informed search? Suggest a suitable heuristic cost function for the 8-puzzle.

[6]

Question 2 Knowledge Representation and Reasoning

(a) (i) Explain what is meant by *transitivity* of inference.

(ii) Give examples of transitive and non-transitive inferences.

[4]

(b) (i) Explain what is meant by *forward-* and *backward-* chaining.

(ii) Suppose the following is an excerpt from the user's manual for a domestic heating system. Encode the information as a set of if-then rules and use backward-chaining to test the hypothesis that the water pressure is too low given observations that there is no central heating and the gauge is below 1.

> If there is no central heating and no hot water then either there is a power failure or the water pressure is too low. Low water pressure is indicated by the gauge showing less than 1. The red light will be off if there is a power failure. If the central heating is on but there is no hot water, there is a valve problem.

[7]

(c) (i) What is meant by *frames* and *inheritance* in the context of knowledge representation?

(ii) Suppose a frame-based semantic network encodes the following information. What problems might arise when processing queries about dolphins? How could the inheritance mechanism be restricted to avoid this problem?

- Animals are mammals, birds or fish.
- Animals are marine or land-based.
- Mammals do not swim.
- Marine animals swim.
- Dolphins are mammals.
- Dolphins are marine animals.

[8]

(d) (i) Explain what is meant by *soundness* and *completeness* of an inference system.

(ii) Explain, and give an example of *abduction*. Is this a sound method of inference? Justify your answer.

[6]

Question 3 Formal Logic

(a) Using truth tables, show whether the following statements of Propositional Logic are equivalent:

$$(p \vee q) \rightarrow r$$
$$(p \rightarrow r) \vee (q \rightarrow r)$$

[4]

(b) Using only the symbols $\neg$ and $\vee$, construct formulas with the same truth-tables as

(i) $p \wedge q$
(ii) $p \rightarrow q$
(iii) $p \leftrightarrow q$

[6]

(c) Give the meaning of each the following formulas of Predicate Calculus in ordinary English,

(i) $\forall x(Swims(x) \rightarrow \neg Bird(x))$
(ii) $\neg\exists x(Feathered(x) \wedge Flies(x) \wedge \neg Bird(x))$
(iii) $\forall x(Bird(x) \wedge Fly(x))$
(iv) $\neg\exists x(Albatross(x) \wedge \exists y(Eagle(y) \wedge \neg Larger(xy)))$

[3]

(d) Construct formulas with the same meanings as 3c(ii) and (iv) using only the quantifier $\forall$ plus any necessary Boolean operators

Construct formulas with the same meanings as 3c(i) and (iii) using only the quantifier $\exists$ plus any necessary Boolean operators;

[6]

(e) Using semantic tableau (or other proof-theoretic technique) prove the non-existence of unicorns given the following premises. You will first need to express these as formulas of Predicate Calculus.

1. Unicorns are equine quadrupeds.
2. Unicorns have horns.
3. Anything equine is a mammal.
4. No mammals have horns.

[6]

Question 4 Natural Language

(a) Describe three different ways natural language expressions can be ambiguous, giving examples and formal representations where appropriate.

[4]

(b) A natural language system has the following grammatical and lexical rules:

s	$\longrightarrow$	np vp	det	$\longrightarrow$	[the]	v	$\longrightarrow$	[must]
np	$\longrightarrow$	det n	det	$\longrightarrow$	[a]	v	$\longrightarrow$	[will]
vp	$\longrightarrow$	v vp	n	$\longrightarrow$	[cat]	v	$\longrightarrow$	[not]
vp	$\longrightarrow$	v	n	$\longrightarrow$	[fish]	v	$\longrightarrow$	[sleep]
						v	$\longrightarrow$	[eat]

Draw syntax trees for the following sentences according to the above grammar:

(i) The cat will not sleep.

(ii) A fish must swim.

How can the grammar be modified so that it will *not* generate the following sentences, but will still generate (i) and (ii)?

(iii) *The cat not will swim.

(iv) *The cat sleep not.

(v) *A fish must will.

Draw syntax trees for examples (i) and (ii) above according to your new grammar.

[9]

(c) Show how we can use the lambda-calculus to translate the sentence *Every fish swims* into first-order predicate calculus.

[6]

(d) Explain the distinction between *regular* and *context-free* grammars. What evidence is there that natural languages require at least context-free grammars?

[6]

Question 5 Philosophy of AI

(a) (i) Describe John Searle's "Chinese Room" thought experiment.

(ii) Do you agree that the Chinese Room argument is "a decisive refutation of the more ambitious claims of artificial intelligence"? (John Searle, in *The Penguin Dictionary of Philosophy*, 2000, p514).

(iii) Could a Martian philosopher use Searle's line of argument to prove that humans are not conscious?

[12]

(b) In the early 19th century Lady Ada Lovelace wrote that Charles Babbage's Analytical Engine "has no pretensions to originate anything. It can do *whatever we know how to order it to perform*". Does the same restriction apply to modern electronic computers programmed with AI systems?

[7]

(c) Describe three types of application where AI technology has already made a significant contribution.

[6]