UNIVERSITY OF LONDON

GOLDSMITHS COLLEGE

BSc Examination 2007

COMPUTING

IS53024A (CIS341)
Artificial Intelligence

Duration: 2 hours and 15 minutes

Date and Time:

You should answer three questions in this paper. There are five questions in total. All questions are worth 25 marks. The marks for each part of a question are indicated at the end of the part in [.] brackets.

No calculators should be used.

THIS PAPER MUST NOT BE REMOVED FROM THE EXAMINATION ROOM

1. **This question is about search**

(a) Uninformed search.

i. What is meant by an uninformed search strategy? [2]

ii. What does it mean for a search strategy to be complete? [2]

iii. What does it mean for a search strategy to be optimal? [2]

iv. Describe depth first and breadth first search, and for each decide whether they are optimal and complete. [2]

(b) Informed search.

i. What is the difference between informed and uninformed search? [2]

ii. Suppose for a node n in the search space we define the following functions:

(i) $g(n)$ = the path cost from the start node to n.

(ii) $h(n)$ = the estimated cost of the cheapest path from the state at node n to a goal state.

(iii) $f(n) = g(n) + h(n)$ estimated cost of the cheapest solution through n.

Describe greedy search and A* search in terms of these functions. [2]

iii. What must be true about any heuristic $h(n)$ used for A*, in order for it to be optimal? [2]

Consider the road map given in the following table. The agent starts at A and wants to plan a route to the Destination.

From	To	distance
A	B	50
B	C	150
C	Destination	80
A	E	40
E	Destination	220
A	F	150
F	G	20
G	Destination	140

The following table gives the *direct* distance of all towns to the destination.

From	To	distance
A	Destination	250
B	Destination	230
C	Destination	70
E	Destination	210
F	Destination	150
G	Destination	100

iv. Calculate $h(n)$, $g(n)$ and $f(n)$ for each of the nodes A, C, E and F. [4]

v. Describe what happens when greedy search is used. [4]

vi. Describe what happens when A* search is used. [3]

2. **This question is about logical agents**

(a) i. What is mean by entailment? [2]

ii. What is meant by logical inference? [2]

iii. What does it mean to say that an inference procedure is sound and complete? [2]

(b) Consider an example of the Wompus world as shown in the table below.

It has a wompus at square (1,3) and pits at (3,1) and (4,3) and there is gold at (2,3). The rules of the environment are as follows.

i. Squares adjacent to pits are breezy. (Adjacent squares do not include diagonal squares.)
ii. Squares adjacent to the wompus, and the squares containing the wompus have a stench.

WOMPUS	GOLD		PIT
		PIT	

i. Copy and complete the picture to include this information using a B for breeze, and an S for stench. [3]

ii. The goal of the agent is to get to the square where the gold is. It can perceive a breeze and/or a stench if it is in a square where these events are happening. This perception is simply in the form of a tuple. For example, (yes,no) would state that the agent could sense a breeze and no stench. Assume the agent is aware that it is in a 4-4 grid, that there is only 1 wompus, that the agent starts from (1,1) and that the agent achieves its goal as soon as it is located in the same grid location as the gold. Describe a possible route that is "risk free" for the agent to get to the gold assuming that if the agent enters a square with a pit or a wompus it dies. An agent can only move to adjacent squares. Justify your answer. [3]

(c) The agent's knowledge base also includes the following rules.

i. (R1) If there is no stench at (1,1) then it implies that there is no wompus at (1,1) and no wompus at (1,2) and no wompus at (2,1)
ii. (R2) If there is a stench at (1,2) then it implies that there is a wompus at (1,2) or there is a wompus at (1,1) or there is a wompus at (2,2) or there is a wompus at (1,3)
iii. (R3) If there is no stench at (2,2) then it implies that there is no wompus at (2,2) and no wompus at (1,2) and no wompus at (2,1) and no wompus at (3,2) and no wompus at (2,3)

Using propositions of the form $W_{(i,j)}$ and $\neg\ W_{(i,j)}$ which assert that there is a wompus at (i,j) and no wompus at (i,j), respectively, write these three rules using first order propositional logic. [6]

(d) Because of the agent's percepts at (1,1) the agent can add the following predicates to its knowledge base.

$$\neg S_{(1,1)}, \quad \neg B_{(1,1)}$$

Suppose the agent then moves to (1,2) and then (albeit crazily as it might die) to (2,2).

Write down all the information the agent would have in its knowledge base after these moves? [4]

(e) Given this knowledge base (which includes the percepts and rules) and the seven inference rules of propositional logic (given below), *sketch* how you would go about proving that there is no wompus at (1,3). *Please note that you are not expected to produce a formal proof.* [3]

The seven inference rules for propositional logic

- Rule1 (MP)

$$\frac{\alpha \Rightarrow \beta, \qquad \alpha}{\beta}$$

- Rule2 (AE)

$$\frac{\alpha_1 \wedge \alpha_2 \wedge \ldots \wedge \alpha_n}{\alpha_i}$$

- Rule3 (AI)

$$\frac{\alpha_1, \alpha_2, \ldots \alpha_n}{\alpha_1 \wedge \alpha_2 \wedge \ldots \wedge \alpha_n}$$

- Rule4 (OI)

$$\frac{\alpha_i}{\alpha_1 \vee \alpha_2 \vee \ldots \vee \alpha_n}$$

- Rule5 (DNE)

$$\frac{\neg\neg\alpha}{\alpha}$$

- Rule6 (UR)

$$\frac{\alpha \vee \beta, \qquad \neg\beta}{\alpha}$$

- Rule7 (R)

$$\frac{\alpha \vee \beta, \qquad \neg\beta \vee \gamma}{\alpha \vee \gamma}$$

3. **This question is about multi-agent encounters**

Suppose we have a situation where two agents have two possible actions (strategies) they can perform, either cooperate (C) or defect (D) and that these are performed simultaneiously.

$$Action = \{cooperate, defect\}$$

Also assume that agent i and agent j have utility functions for each possible outcome, u_i and u_j, given below.

$$u_i(D,D) = 2 \qquad u_i(D,C) = 4 \qquad u_i(C,D) = 1 \qquad u_i(C,C) = 3$$

$$u_j(D,D) = 2 \qquad u_j(D,C) = 1 \qquad u_j(C,D) = 4 \qquad u_i(D,C) = 3$$

These can be represented in the following payoff matrix. This encounter is commonly known as the prisoners dilemma.

	i defects	i cooperates
j defects	2 (j: 2)	4 (j: 1)
j cooperates	1 (j: 4)	3 (j: 3)

(a) Explain what is meant by a *strongly dominant strategy*? [2]

(b) What is meant by *Nash Equilibrium*? [3]

(c) State the role of both dominant strategies and Nash Equilibrium in determining the best strategy for an agent. [2]

(d) Give an explanation is to why there is no dominant strategy in the prisoners dilemma. [2]

(e) Isolate any Nash equlibria in the prisoners dilemma. [2]

(f) Explain why both agents will choose to defect even though the optimal strategy would appear to be for both to cooperate. [2]

(g) Consider the following interaction scenarios [12]

	i defects	i cooperates
j defects	4 (j: 4)	4 (j: 1)
j cooperates	1 (j: 4)	1 (j: 1)

	i defects	i cooperates
j defects	0 (j: 0)	3 (j: 1)
j cooperates	1 (j: 3)	2 (j: 2)

For each matrix:

i. analyse the scenarios informally to determine what agent i should do
ii. analyse the scenarios informally to determine what agent j should do
iii. determine which strategies are strongly dominated for i (if any)
iv. determine which strategies are strongly dominated for j (if any)
v. identify any Nash Equilibria
vi. identify a possible real world interaction that is modelled by the matrix

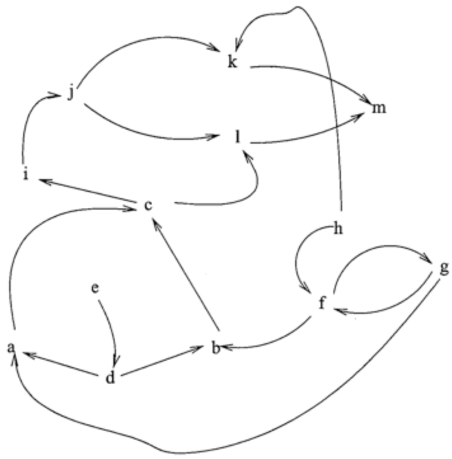

Figure 1: An abstract argument system

4. **This question is about agents and argumentation**

(a) This part of the question is concerned with agents and agent architectures.

i. No one really agrees on what makes something a computational agent but give four attributes that are commonly associated with agency. [4]

ii. Explain what is mean by a deliberative agent architecture, a reactive agent architecture and a hybrid agent architecture and describe the advantages and limitations of each. [6]

(b) The second part of this question is concerned with logic-based argument systems. In the context of logic-based argument systems, define the notion of:

i. one argument *attacking* another; [1]
ii. an *acceptable* argument; and [1]

Consider the abstract argument system shown in Figure 1 and explain the status of the following arguments (i.e whether they are *in* or *out* justifying your answer in each case. [13]

i. a

ii. b

iii. c

iv. d

v. e

vi. f

vii. g

viii. h

ix. i

x. j

xi. k

xii. l

xiii. m

5. **This question is concerned with negotiation in task-oriented domains.**

Consider the following scenario. Agent Ag_1 has been assigned the tasks $\{t_1, t_2\}$ and agent Ag_2 has been assigned the tasks $\{t_3, t_4\}$.

The costs to agent Ag_1 are as follows.

$$c_1(t_1) = 10$$
$$c_1(t_2) = 5$$
$$c_1(t_3) = 1$$
$$c_1(t_4) = 0$$

The costs to agent Ag_2 are as follows

$$c_2(t_1) = 1$$
$$c_2(t_2) = 5$$
$$c_2(t_3) = 1$$
$$c_2(t_4) = 9$$

The agents might be better off if they decide to negotiate and swap their tasks and make a *deal*. The only proviso is that in any deal they must still complete 2 tasks. The agents decide to use the *monotonic concession protocol* for negotiation.

(a) Describe the *monotonic concession protocol* for negotiation. [4]

(b) What is the conflict deal? Describe what is meant by the utility of a deal. What is an individually rational deal? [4]

(c) Describe what is means to say that a deal is *Pareto Optimal*? [2]

(d) There is a way of defining the risk of an agent pulling out of a negotiation. Suppose Ag_1 with utility function u_1 is proposing the deal d_1 and agent Ag_2 is proposing the deal d_2. The risk of agent 1 pulling out of the negotiation and therefore settling for the conflict deal is given by:

$$\frac{u_1(d_1) - u_1(d_2)}{u_1(d_1)}$$

This formula does not work if $u_1(d_1) = 0$. In this case what is the risk they will pull out and why? [2]

(e) If agents use the Zeuthen strategy to negotiate then: [3]

i. What should an agent's first proposal be?
ii. On any given round who should concede?
iii. If an agent concedes, just how much should they concede?

(f) Show what will happen when agents Ag_1 and Ag_2 both use the Zeuthen strategy and the monotonic concession protocol. What is the final utility to both agents in the resulting deal?

(g) Agent Ag_1 has been assigned the tasks $\{t_1, t_2\}$ and agent Ag_2 has been assigned the tasks $\{t_3, t_4\}$.

The costs to agent Ag_1 are as follows.

$$c_1(t_1) = 25$$
$$c_1(t_2) = 30$$
$$c_1(t_3) = 11$$
$$c_1(t_4) = 14$$

The costs to agent Ag_2 are as follows

$$c_2(t_1) = 12$$
$$c_2(t_2) = 19$$
$$c_2(t_3) = 16$$
$$c_2(t_4) = 33$$