King's College London

This paper is part of an examination of the College counting towards the award of a degree. Examinations are governed by the College Regulations under the authority of the Academic Board.

Degree Programmes MSc, MSci

Module Code 7CCSMAMS
Module Title Agents and Multi-Agent Systems
Examination Period January 2019 (Period 1)

Time Allowed Two hours
Rubric ANSWER THREE OF FOUR QUESTIONS.

All questions carry equal marks. If more than three questions are answered, the three answers with highest marks will count.

ANSWER EACH QUESTION ON A NEW PAGE OF YOUR ANSWER BOOK AND WRITE ITS NUMBER IN THE SPACE PROVIDED.

Calculators Calculators may be used. The following models are permitted: Casio fx83 / Casio fx85.
Notes Books, notes or other written material may not be brought into this examination

PLEASE DO NOT REMOVE THIS PAPER FROM THE EXAMINATION ROOM

TURN OVER WHEN INSTRUCTED

1.

a. What are the main properties of an intelligent agent? Make sure you explain what is meant by each of these properties.

[4 marks]

b. Five ongoing trends in computing that have played an important part in leading to the development of the field of multi-agent systems are:

- ubiquity,
- interconnection,
- intelligence,
- delegation,
- human-orientation.

i. Explain what is meant by each of these computing trends.

[5 marks]

ii. Explain how these trends have influenced the development of the field of multi-agent systems.

[5 marks]

c. Give an example of an application that would be well suited to being implemented as a multi-agent system and explain why this is the case, making reference to the properties you gave for part 1a. (Your example does not have to be an application that exists already; rather it should address a problem that is suited to the multi-agent system approach.)

[5 marks]

QUESTION 1 CONTINUES ON NEXT PAGE

SEE NEXT PAGE

d. A utility function over runs is defined by the function $u^r : \mathcal{R}^E \rightarrow \mathbb{R}$. A utility function over environment states is defined by the function $u^e : E \rightarrow \mathbb{R}$.

(Recall: E is the set of all possible environment states; Ac is the set of all possible actions; $\mathcal{R}^E$ is the set of all possible runs over E and Ac that end with an environment state; $\mathbb{R}$ is the set of real numbers.)

i. Is the following statement true: "Every utility function defined over runs can be expressed by a utility function defined over states"?
If true, show how a utility function defined over runs can be expressed by a utility function defined over states. If not true, then give a counter example of a utility function defined over runs that cannot be expressed by a utility function defined over states.

[7 marks]

ii. Is the following statement true: "Every utility function defined over states can be expressed by a utility function defined over runs"?
If true, show how a utility function defined over states can be expressed by a utility function defined over runs. If not true, then give a counter example of a utility function defined over states that cannot be expressed by a utility function defined over runs.

[7 marks]

2.

a. Below is some knowledge that an agent has about films, where X is a variable that can be instantiated by any constant and constants all start with lower-case letters.

$$NinetiesFilm(homealone)$$
$$ActionFilm(homealone)$$
$$NinetiesFilm(X) \wedge ActionFilm(X) \rightarrow \neg Watch(X)$$
$$DirectedBy(johnhughes, homealone)$$
$$DirectedBy(johnhughes, X) \rightarrow Watch(X)$$
$$DirectedBy(johnhughes, X) \rightarrow \neg ActionFilm(X)$$

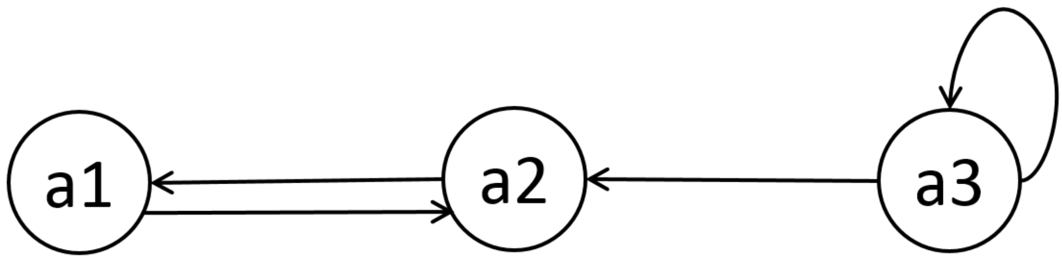
i. Using the knowledge above, it is possible to construct two arguments that *rebut* one another. Identify two such arguments, giving the support and the claim of each.

[3 marks]

ii. Using the knowledge above, it is possible to construct two arguments such that one *undercuts* the other. Identify two such arguments, giving the support and the claim of each. Make it clear in your answer which argument undercuts the other.

[3 marks]

b. The figure below shows an abstract argumentation framework.



i. For the abstract argumentation framework above, give all valid labellings under the *grounded semantics*.

[4 marks]

ii. For the abstract argumentation framework above, give all valid labellings under the *preferred semantics*.

[4 marks]

c. Give an example of an application for which it would be appropriate to communicate using an argumentation-based dialogue. Explain why an argumentation-based dialogue is appropriate in this case.

[8 marks]

d. When an agent is strategising in an argumentation-based dialogue, it can be useful to take into account what it knows about the other dialogue participant.

i. Describe two types of information the strategising agent might have about the other dialogue participant that could be helpful to the strategising agent in deciding which arguments to put forward during the dialogue.

[6 marks]

ii. It is typically the case that any knowledge the strategising agent has about the other dialogue participant is *uncertain*. Briefly explain why this is a challenge when strategising for argumentation-based dialogues.

[5 marks]

3.

a. The following is a description of a lift using the intentional stance.

> A lift is capable of moving from floor to floor. Its sole desire is to help humans to get to where they want to be. We tell the lift that we want its help by pressing its call button and we tell the lift where we want to get to by pressing the appropriate floor button in the lift. The lift will travel to a floor if it believes there is someone waiting there who wants its help, or if it believes that it is carrying a passenger who wants to go to that floor.

Explain whether you think it is (a) *useful* and (b) *legitimate* to discuss the behaviour of a lift in this way, giving your reasons for your answer.

[7 marks]

b. For each of the following pairs of environment characteristics, explain with the aid of examples which of the pair is harder for an agent designer to deal with and why this is the case.

i. Static or dynamic.

[3 marks]

ii. Episodic or non-episodic.

[3 marks]

c. Consider the following coin tossing game, where the agent first makes a declaration and then tosses two coins. The agent receives a reward depending on the declaration it makes and the outcome of the coin toss.

- An agent has two normal coins, coin 1 and coin 2. Each has one side designated as heads and the other side designated as tails.
- When tossing either coin, there is a 0.5 probability of getting heads and a 0.5 possibility of getting tails. When tossing both coins there are thus four possible outcomes, each equally likely, where the first letter represents the outcome of tossing coin 1 and the second letter represents the outcome of tossing coin 2: `HH`, `HT`, `TT`, `TH`. (E.g., `TH` means coin 1 came up tails and coin 2 came up heads.)
- Before tossing the coins, the agent must declare one of two options:
  - *At least one head.*
  - *Two heads.*
- After making its declaration, the agent tosses both coins.
- If the agent has declared "At least one head" and one of the following outcomes occurs, the agent receives a utility of 5: `HH`, `HT`, `TH`. Otherwise the agent receives a utility of 0.
- If the agent has declared "Two heads" and the following outcomes occurs, the agent receives a utility of 10: `HH`. Otherwise the agent receives a utility of 0.

If we consider a single round of the game, we can define the possible **environment states** as follows.

e_0: the initial state, before the agent has made its declaration.

e_1: the state where the agent has declared "At least one head" but has not yet tossed the coins.

e_2: the state where the agent has declared "Two heads" but has not yet tossed the coins.

e_{HH}: the state where the agent has tossed the coins and both came up heads.

e_{TT}: the state where the agent has tossed the coins and both came up tails.

e_{TH}: the state where the agent has tossed the coins, coin 1 came up tails and coin 2 came up heads.

e_{HT}: the state where the agent has tossed the coins, coin 1 came up heads and coin 2 came up tails.

There are three possible **actions** that the agent can perform, as follows.

α_1: the action where the agent declares "At least one head". This action can only be performed in state e_0.

α_2: the action where the agent declares "Two heads". This action can only be performed in state e_0.

α_{toss}: the action where the agent tosses the two coins. This action can only be performed in either state e_1 or in state e_2.

i. Write down all the possible runs of the system.

[4 marks]

ii. Write down the state transformer function τ that represents the behaviour of this environment.

[6 marks]

iii. There are two possible agents we can define for the coin tossing game as follows.

- $Ag_1(e_0) = \alpha_1$, $Ag_1(e_1) = \alpha_{toss}$.
- $Ag_2(e_0) = \alpha_2$, $Ag_2(e_2) = \alpha_{toss}$.

What is the *expected utility* of each agent? Make sure you show your workings.

[4 marks]

d. What is a predicate task specification? Explain, with an example, why a predicate task specification might be preferable to a utility function that assigns a real number to a run of the environment.

[6 marks]

4.

a. Consider the following voter profile:

20 voters:	$B \succ C \succ A \succ D$
50 voters:	$C \succ B \succ A \succ D$
15 voters:	$D \succ B \succ C \succ A$
5 voters:	$A \succ C \succ B \succ D$

Identify who is the winner under each of the following voting rules. Show your workings.

- *Plurality*.
- *Instant runoff*.
- *Borda count*.
- *Copeland rule*.

[8 marks]

QUESTION 4 CONTINUES ON NEXT PAGE SEE NEXT PAGE

b. Consider the following voter profile:

3 voters:	$A \succ B \succ C$
2 voters:	$B \succ C \succ A$
1 voter:	$B \succ A \succ C$
1 voter:	$C \succ A \succ B$

The winner is determined through a linear sequence of pairwise elections with the following agenda:

$$A, C, B$$

i. What is the outcome? Show your workings.

[2 marks]

ii. Construct the majority graph for this voter profile.

[2 marks]

iii. Is it possible to fix the agenda to give a different winner than you determined for Question 4.b.i? Explain the reasons for your answer.

[3 marks]

c. Consider the following voter profile representing the *truthful* preferences of Alice, Bob, and Charlie:

Alice:	$B \succ C \succ A \succ D$
Bob:	$C \succ B \succ A \succ D$
Charlie:	$D \succ C \succ B \succ A$

Alice, Bob, and Charlie decide to hold a vote which will be decided according to the *Borda count* rule, with ties decided randomly.

In whose interest is it to vote strategically and *falsely* report their preference (assuming they know the truthful preferences of the other two voters)? Specify the person as well as the ordering they should report instead of their true preference. Show your workings.

[6 marks]

d. Consider the following voter profile:

4 voters:	$A \succ B \succ C$
3 voters:	$B \succ C \succ A$
2 voters:	$B \succ A \succ C$
2 voters:	$C \succ A \succ B$

i. Identify the *Condorcet winner*. Show your workings.

[2 marks]

ii. Suppose that (s_1, s_2, s_3) is an arbitrary *Positional Scoring Rule (PSR)*, where s_1, s_2, s_3 are positive whole numbers such that $s_1 \geq s_2 \geq s_3$ and $s_1 > s_3$. Show that this voting rule does not select the Condorcet winner.

[10 marks]