PAPER CODE NO. **COMP310**

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REVISION EXAMINATIONS

Multiagent Systems

TIME ALLOWED : Two and a Half Hours

INSTRUCTIONS TO CANDIDATES

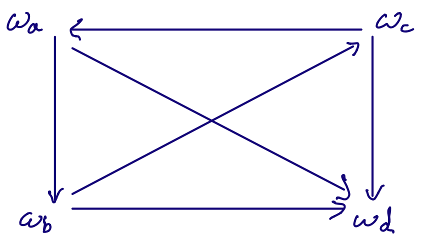
This is a mock paper containing four questions - solutions are available.

If you attempt to answer more questions than the required number of questions (in any section), the marks awarded for the excess questions answered will be discarded (starting with your lowest mark).

1. In the following linear sequential pairwise elections, candidates are shown, and the outcomes (i.e. the candidate that would win a pairwise election) is given, where $\Omega = \{\omega_a, \omega_b, \omega_c, \omega_d\}$:

$$
\begin{array}{ll}
\{\omega_a, \omega_b\} & \longrightarrow \omega_a \\
\{\omega_a, \omega_c\} & \longrightarrow \omega_c \\
\{\omega_a, \omega_d\} & \longrightarrow \omega_a \\
\{\omega_b, \omega_c\} & \longrightarrow \omega_b \\
\{\omega_b, \omega_d\} & \longrightarrow \omega_d \\
\{\omega_c, \omega_d\} & \longrightarrow \omega_c
\end{array}
$$

(a) Draw the majority graph that would represent these outcomes. **(3 marks)**



(b) Give an agenda that would result in the outcome ω_a in a linear pairwise election, if such an agenda exists. If not, explain why. **(3 marks)**

$(\omega_b, \omega_c, \omega_d, \omega_a)$

ω_b vs ω_c
$\rightarrow \omega_b$ vs ω_d
$\rightarrow \omega_d$ vs ω_a
$\rightarrow \omega_a$

(c) Give an agenda that would result in the outcome ω_c in a linear pairwise election, if such an agenda exists. If not, explain why. **(3 marks)**

$(\omega_a, \omega_b, \omega_c, \omega_d)$

ω_a vs ω_b
$\rightarrow \omega_a$ vs ω_c
$\rightarrow \omega_c$ vs ω_d
$\rightarrow \omega_c$

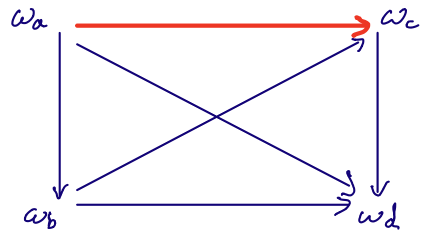
(d) Define a condorcet winner. Is there a condorcet winner in this linear sequential pairwise election? If so, what is it and why? If not, why not? **(4 marks)**

A condorcet winner is the winner of a linear sequential pairwise election for all possible agendas.

In the above majority graph, there is no overall winner, and thus no condorcet winner.

(e) If you wanted to change this setting so that ω_a was a condorcet winner, what one pairwise election would you change, and why? **(2 marks)**

If the outcome of the pairwise election (ω_a, ω_c) was changed so that ω_a was the winner, then the result would be the majority graph shown opposite.



Note that no other candidate can beat ω_a

(f) The *Gibbard-Satterthwaite Theorem* seems to be a very negative result in social choice theory. Explain what you understand by the Gibbard-Satterthwaite Theorem and its implications, and explain the implications of computational complexity with respect to this result. **(5 marks)**

The pareto property (or pareto condition) states that an outcome is Pareto efficient if it is the case that if every voter ranks outcome ω_i over ω_j, then ω_i will be more preferred in the final ranking than ω_j

The Gibbard-Satterthwaite Theorem states that the only non-manipulable voting method that satisfies the Pareto condition is a dictatorship.

However, this only states that manipulation is possible in principal, but says nothing about how it can be achieved in practice, which can be computationally complex. Misrepresentation is where an agent misrepresents its true preferences, given knowledge of the other voters preferences, to change the final outcome.

(g) *Arrow's theorem* is a fundamental impossibility result in social choice theory. Explain what you understand by Arrow's theorem, and its implications. **(5 marks)**

This theorem states that for elections with more than two candidates, the only voting procedure satisfying the Pareto condition and the Independence of Irrelevant Alternatives' condition is a dictatorship.

The Independence of Irrelevant Alternatives (IIA) condition states the following:

Assume that, in the final outcome of a voting game, an outcome ω_i is preferred over ω_j (ie $\omega_i \succ^* \omega_j$).

If some voter that prefers ω_i over ω_j then changes its preferences, but in such a way that ω_i is prefered over ω_j (ie the preference order of the other outcomes change in some way), then IIA states that this should not affect the final outcome.

This result is a negative result, as it states that voting procedures are flawed and, when there are more than two candidates, do not satisfy "good" conditions.

2. In Searle's theory of Speech Acts, a speech act consists of two components, a *performative verb* and *propositional content*. Briefly explain what the following two KQML expressions mean:

(a)
```
(ask-if
    :sender       A
    :receiver     B
    :language     OWL
    :ontology     pizza
    :reply-with   q1
    :content ( (margherita isa Pizza)
               (margherita hasTopping mozzarella) )
)
```

(4 marks)

The performative "ask-if" poses the question (from agent A to agent B) if it is true that there is an instance of the class Pizza that is called "margherita" that has mozzarella as a topping.

(b)
```
(tell
    :sender       A
    :receiver     B
    :language     OWL
    :ontology     pizza
    :reply-with   q1
    :content (not (hawaiian isa ItalianPizza))
)
```

(4 marks)

The performative "tell" tells agent B that the class hawaiian is not a subclass of ItalianPizza

Note that for both questions you should be able to identify what the performative means (or at least indicate what it could mean) and relate it to the content.

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The Java Agent Development Environment provides a software framework to support the development of agents, whereby each agent is created in a threaded object known as a container. Each container is registered with the main container, which provides various services, including the *Agent Management System* and the *Directory Facilitator*.

(c) Briefly describe the role of the *Agent Management System*. **(4 marks)**

This is the component that creates and records the location of an agent, as well as associating a name with the agent. The location may include an IP address and a port code, and allows an agent to be found just by using its name. It is also responsible for destroying agents.

(d) Briefly describe the role of the *Directory Facilitator*. **(4 marks)**

This provides a yellow-pages based discovery service, to allow agents to locate other agents based on the services that they provide.

It is often useful to distinguish ontologies based on their role (i.e. how they are going to be used). Briefly describe the role of each of the following:

(e) Upper Ontology **(3 marks)**

An upper ontology contains concepts that are very general and that can be used to describe the world. It defines very general concepts (eg "thing", "non-living thing") that are common across all domains. Often, upper ontologies are used to support semantic interoperability between Domain Ontologies

(f) Domain Ontology **(3 marks)**

A domain ontology is an ontology that describes a particular domain or part of the world. For example a medical domain ontology could describe concepts relating to medical terminology.

(g) Application Ontology **(3 marks)**

An application ontology defines the concepts used by a specific application, building on the concepts defined in a domain ontology.

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3. In the context of cooperative games, consider the following marginal contribution net:

$a \wedge c \to 8$	Rule 1
$b \wedge \neg a \to 5$	Rule 2
$c \wedge \neg a \to 2$	Rule 3
$c \to 5$	Rule 4
$b \wedge \neg c \to 3$	Rule 5
$d \to 9$	Rule 6
$d \wedge c \to 4$	Rule 7

Let ν be the characteristic function defined by these rules. Give the values of the following, and in each case, justify your answer with respect to the rule or rules of the above marginal contribution net:

Note this is technically incorrect and should be $\nu(\emptyset)$

a) $\nu(\{\varnothing\})$ **(2 marks)**

No rules apply, and therefore $\nu(\emptyset) = 0$

b) $\nu(\{a, c\})$ **(2 marks)**

This matches rule 1 and rule 4

$\therefore \nu(\{a,c\}) = 8 + 5 = 13$

c) $\nu(\{b, c, d\})$ **(2 marks)**

This matches rules 2, 3, 4, 6 and rule 7

$\therefore \nu(\{b,c,d\}) = 5 + 2 + 5 + 9 + 4 = 25$

d) $\nu(\{b, c\})$ **(2 marks)**

This matches rules 2, 3 and rule 4

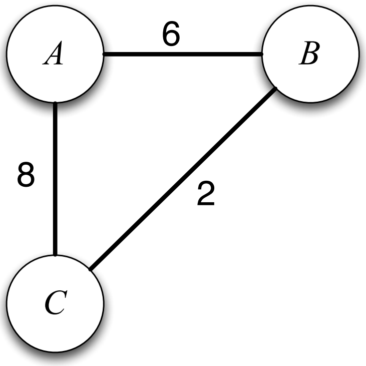
$\therefore \nu(\{b,c\}) = 5 + 2 + 5 = 12$

e) $\nu(\{a, b, c, d\})$ **(2 marks)**

This matches rules 1, 4, 6 and rule 7

$\therefore \nu(\{a,b,c,d\}) = 8 + 5 + 9 + 4 = 26$

The following figure shows an induced sub-graph for a coalition game with agents $Ag = \{a, b, c\}$.



(f) Compute the Shapley values for the agents a, b, and c. You should show the relevant steps in your answer that are used to derive the answer. (**9 marks, 3 for each agent**)

The shapley value for each agent is determined by using the symmetry axiom, to share the value of each edge between its two nodes, and the additivity axiom to treat each edge as a separate game.
The shapley value (for subgraphs with no cycles) can be derived as follows:

$$\varphi_i = \frac{1}{2} \sum_{j \neq i} w_{i,j}$$

$$\varphi_a = \frac{1}{2}(6+8) = 7$$

$$\varphi_b = \frac{1}{2}(6+2) = 4$$

$$\varphi_c = \frac{1}{2}(8+2) = 5$$

4. Twenty three friends make plans to go to see a movie, and decide to use a Social Choice Function to decide on a genre. Each friend can be considered as an agent, such that we have $n = 23$ agents. The set of outcomes can be defined as

$$\Omega = \{\text{action, romance, comedy, drama, horror}\}$$

The preference schedule is shown below, and states how many votes are given for each preference order:

Votes	4	7	3	9
First Choice	action	romance	comedy	drama
Second Choice	drama	drama	action	horror
Third Choice	comedy	horror	drama	action
Forth Choice	romance	action	horror	romance
Fifth Choice	horror	comedy	romance	comedy

Given this preference schedule, calculate the winner (and in each case show the working) using:

a) Plurality voting **(2 marks)**

We simply count the number of votes that place an outcome as first choice. Thus, we have

action: 4 votes
romance: 7 votes
comedy: 3 votes
drama: 9 votes
horror: 0 votes

Drama wins

b) Alternative vote **(5 marks)**

In this case, we proceed in rounds, where at the end of each round, the outcome with the least number of votes is eliminated, until we have an outcome with a majority

	Round			
Outcome	1	2	3	4
action	4	4	4+3	—
romance	7	7	7	7
comedy	3	3	—	—
drama	9	9	9	4+3+9
horror	0	—	—	—

Total number of votes: 23
Votes needed for majority: 12

Round 1: we eliminate horror
Round 2: we eliminate comedy
Round 3: we can either eliminate action or romance (Note that the method for resolving ties is undefined in the alternative vote system).
- In this case we eliminate action

Drama wins

c) The following payoff matrix (A) is for the “chicken”:

		i defect	i coop
j	defect	1 1	2 4
	coop	4 2	3 3

The following payoff matrix (B) is for the “matching pennies”:

		i defect	i coop
j	defect	-1 1	1 -1
	coop	1 -1	-1 1

The following payoff matrix (C) is for some other, unnamed game:

		i defect	i coop
j	defect	5 3	1 2
	coop	0 2	0 1

For each of these payoff matrices:

(i) Identify all (pure strategy) Nash Equilibria; (**6 marks**)

A: CD and DC

B: None

C: DD

(i) Identify all Pareto optimal outcomes; (**6 marks**)

A: CC, CD, DC

B: all of them

C: DD

Note that in my revision notes entitled Mock Paper, Q5, it states that none of the Matching Pennies are pareto optimal. This was a typo

(iii) Identify all outcomes that maximise social welfare. (**6 marks**)

A: CC, CD, DC

B: All (this is a zero sum game)

C: DD