PAPER CODE NO.
COMP310

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UNIVERSITY OF LIVERPOOL

SECOND SEMESTER EXAMINATIONS 2014/15

Multiagent Systems

TIME ALLOWED : Two and a Half Hours

INSTRUCTIONS TO CANDIDATES

Answer **FOUR** questions.

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).

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1. An agent has been described as *"... a computer system that is situated in some environment, and that is capable of autonomous action in that environment in order to meet its desired objectives..."* As such, it can be modelled abstractly.

(a) Explain what is meant by a *predicate task specification*, and how such a specification relates to utility function over runs. **(5 marks)**

(b) Explain what is meant by an *achievement* task. **(5 marks)**

(c) Explain what is meant by a *maintenance* goal. **(5 marks)**

(d) According to McCarthy, the *intentional stance* can be used to explain and predict the behaviour of machines. However, it is not always useful to do so. Give a brief explanation of what is meant by the intentional stance, and explain when and why it is useful to use the intentional stance of a machine. **(10 marks)**

2. The following pseudo-code defines a control loop for a practical reasoning ("BDI") agent:

```
1.  B := B_0;
2.  I := I_0;
3.  while true do
4.      get next percept ρ;
5.      B := brf(B, ρ);
6.      D := options(B, I);
7.      I := filter(B, D, I);
8.      π := plan(B, I);
9.      while not empty(π) do
10.         α := hd(π);
11.         execute(α);
12.         π := tail(π);
13.         get next percept ρ;
14.         B := brf(B, ρ);
15.         if not sound(π, I, B) then
16.             π := plan(B, I);
17.         end-if
18.     end-while
19. end-while
```

(a) Recall that "*Practical Reasoning = deliberation + means end reasoning*". With reference to the above pseudo-code, answer the following questions:

- (i) What commitment protocol is used in this code? **(1 mark)**
- (ii) Which line or lines are responsible for the *deliberation* in the above control loop? **(2 marks)**
- (iii) Which line or lines are responsible for the *means end reasoning* in the above control loop? **(2 marks)**

(b) Again, with reference to the above pseudo-code, explain the purpose/role of the following components:

- (i) The percept ρ. **(2 marks)**
- (ii) The $brf(B, \rho)$ function. **(2 marks)**
- (iii) The $sound(\pi, I, B)$ function. **(2 marks)**
- (iv) The $tail(\pi)$ function. **(2 marks)**

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(c) A variant of the Blocksworld scenario is represented by an ontology with the following formulae:

$On(x, y)$	obj x on top of obj y
$OnTable(x)$	obj x is on the table
$Clear(x)$	nothing is on top of obj x
$Holding(x)$	arm is holding x
$ArmEmpty$	arm is not holding any object

An agent has a set of actions Ac , such that $Ac = \{Grab, Build, Drop, Demolish\}$ given below. However, due to mistakes made by the agent developer, there may be one or more errors in the action definitions.

	$Grab(x)$
pre	$Clear(x)$ & $OnTable(x)$ & $ArmEmpty$
del	$OnTable(x)$ & $ArmEmpty$
add	$Holding(x)$

	$Build(x, y)$
pre	$Clear(y)$ & $Holding(x)$
del	$Clear(y)$ & $Holding(x)$
add	$ArmEmpty$ & $On(x, y)$

	$Drop(x)$
pre	$Holding(x)$
del	$Holding(x)$
add	$OnTable(x)$ & $ArmEmpty$ & $Clear(x)$

	$Demolish(x, y)$
pre	$On(x, y)$ & $Clear(y)$ & $ArmEmpty$
del	$On(x, y)$ & $ArmEmpty$
add	$Holding(x)$ & $Clear(y)$

For each of the following planning problems given below, determine if the intention I is possible given Ac and the initial beliefs B_0 (assuming the closed world assumption), and either: if I is possible, give the shortest plan π that achieves it from B_0; otherwise if I is not possible (i.e. the plan is empty, $\pi = \emptyset$) , explain why not.

(i) Given $\langle B_0, Ac, I \rangle$ below, determine the shortest π, or explain why $\pi = \emptyset$.

$$\begin{aligned} Beliefs\ B_0 = \{ \ & ArmEmpty, Clear(A), OnTable(A), \\ & Clear(B), OnTable(B), Clear(C), OnTable(C) \ \} \\ Intention\ I = \{ \ & ArmEmpty, Clear(A), On(A,B), \\ & On(B,C), OnTable(C) \ \} \end{aligned}$$

(4 mark)

(ii) Given $\langle B_0, Ac, I \rangle$ below, determine the shortest π, or explain why $\pi = \emptyset$.

$$\begin{aligned} Beliefs\ B_0 = \{ \ & ArmEmpty, OnTable(A), OnTable(B), Clear(B) \\ & On(C,A), Clear(C) \ \} \\ Intention\ I = \{ \ & ArmEmpty, Clear(A), On(A,B), OnTable(B), \\ & OnTable(C), Clear(C) \ \} \end{aligned}$$

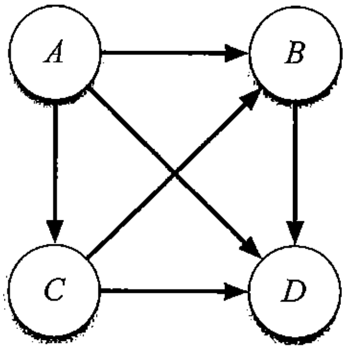
(4 mark)

(iii) Given $\langle B_0, Ac, I \rangle$ below, determine the shortest π, or explain why $\pi = \emptyset$.

$$\begin{aligned} Beliefs\ B_0 = \{ \ & Holding(A), On(B,C), OnTable(C), \\ & OnTable(D), Clear(D) \ \} \\ Intention\ I = \{ \ & Holding(A), On(B,C), OnTable(C), \\ & On(D,B), Clear(D) \ \} \end{aligned}$$

(4 mark)

3. The following figure shows a majority graph for a social choice scenario.



(a) For each of the four candidates, state whether they have a chance of winning in a sequential majority election. Where the answer is "yes", give an example of a linear agenda that would lead to the respective candidate winning. **(4 marks)**

(b) State what is meant by a *Condorcet Winner*, and identify if any of the candidates in the above graph are condorcet winners. **(5 marks)**

(c) 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. **(8 marks)**

(d) *Arrow's theorem* is a fundamental impossibility result in social choice theory. Explain what you understand by Arrow's theorem, and its implications. **(8 marks)**

4. (a) In the context of cooperative games, consider the following marginal contribution net:

$$\begin{aligned} a \wedge b \wedge d &\rightarrow 7 \\ a \wedge b &\rightarrow 3 \\ d &\rightarrow 5 \\ a \wedge c \wedge d &\rightarrow 4 \\ a \wedge c &\rightarrow 2 \end{aligned}$$

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:

(i) $\nu(\{a\})$
(ii) $\nu(\{a, c\})$
(iii) $\nu(\{b, d\})$
(iv) $\nu(\{a, c, d\})$
(v) $\nu(\{a, b, c, d\})$

(10 marks)

(b) A key issue in coalition formation is that of *stability.* Explain what you understand by this issue, and how the *core* tries to capture stability.

(A pass mark in this question may be obtained with an informal answer, but full marks can only be obtained with the formal definition of the core.) **(5 marks)**

(c) The Zeuthen strategy for negotiation answers two questions that must be answered on any given round of negotiation: *who should concede?* and *how much should they concede?* Explain the answers that the Zeuthen strategy provides to these questions.

(10 marks)

5. (a) Combinatorial auctions allow bidders to bid for bundles of goods. In this context, and assuming that we use XOR bids, the following bid is made:

$$B_i = (\{a, b\}, 5)\ XOR\ \{e, f, g\}, 2)\ XOR\ (\{e\}, 2)\ XOR\ (\{c, d, e\}, 4)$$

Let v_{B_i} be a bundle of goods on offer. For each of the following bundles, determine if the bid B_i satisfies the bundle of goods, and state what would be paid for that bundle.

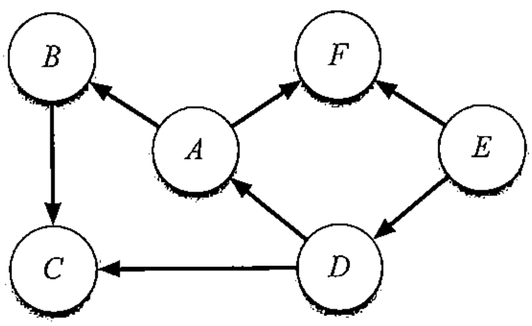
(i) $v_{B_i}(\{e\})$
(ii) $v_{B_i}(\{e, f\})$
(iii) $v_{B_i}(\{c, d, f, g\})$
(iv) $v_{B_i}(\{c, d, e, f, g\})$
(v) $v_{B_i}(\{a, b, c, d, e, f, g\})$

(10 marks)

(b) Explain how the framework of *program equilibria* permits cooperation as a rational outcome in the prisoner's dilemma. Provide an illustration to support your answer.

(9 marks)

(c) The following figure shows an abstract argumentation system.



Compute the grounded extension of this argument system, giving the status (*in* or *out*) of all of the six arguments in the graph, and explain why they are either *in* or *out*.

(1 mark each, for a total of 6 marks)