PAPER CODE NO. COMP310	EXAMINER : Dr T. R. Payne DEPARTMENT : Computer Science	Tel. No. 54251

UNIVERSITY OF LIVERPOOL

SECOND SEMESTER EXAMINATIONS 2012/13

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).

1. (a) The extent to which it is easy or hard to develop an agent that is able to carry out a task in some environment depends on whether the agent's environment is (i) fully observable *vs* partially observable; (ii) static *vs* dynamic; (iii) episodic *vs* non-episodic; and (iv) deterministic *vs* non-deterministic. With the aid of examples, explain what you understand by these distinctions, and how they relate to the difficulty of agent development. **(12 marks)**

(b) Consider the environment $Env_1 = \langle E, e_0, \tau \rangle$ defined as follows:

$$E = \{e_0, e_1, e_2, e_3, e_4, e_5\}$$
$$\tau(e_0 \xrightarrow{\alpha_0}) = \{e_1, e_2, e_3\}$$
$$\tau(e_0 \xrightarrow{\alpha_1}) = \{e_4, e_5\}$$

There are just two agents with respect to this environment, which we shall refer to as Ag_1 and Ag_2:

$$Ag_1(e_0) = \alpha_0$$
$$Ag_2(e_0) = \alpha_1$$

Assume the probabilities of the various runs are as follows:

$$P(e_0 \xrightarrow{\alpha_0} e_1 \mid Ag_1, Env_1) = 0.4$$
$$P(e_0 \xrightarrow{\alpha_0} e_2 \mid Ag_1, Env_1) = 0.5$$
$$P(e_0 \xrightarrow{\alpha_0} e_3 \mid Ag_1, Env_1) = 0.1$$
$$P(e_0 \xrightarrow{\alpha_1} e_4 \mid Ag_2, Env_1) = 0.3$$
$$P(e_0 \xrightarrow{\alpha_1} e_5 \mid Ag_2, Env_1) = 0.7$$

Assume the utility function u_1 is defined as follows:

$$u_1(e_0 \xrightarrow{\alpha_0} e_1) = 8$$
$$u_1(e_0 \xrightarrow{\alpha_0} e_2) = 7$$
$$u_1(e_0 \xrightarrow{\alpha_0} e_3) = 6$$
$$u_1(e_0 \xrightarrow{\alpha_1} e_4) = 9$$
$$u_1(e_0 \xrightarrow{\alpha_1} e_5) = 7$$

Given these definitions, determine the expected utility of the agents Ag_1 and Ag_2 with respect to Env_1 and u_1, and explain which agent is optimal with respect to Env_1 and u_1. Include an explanation of your calculations in your solution. **(13 marks)**

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

```
B := B0;
I := I0;
while true do
     get next percept ρ;
     B := brf(B, ρ);
     D := options(B, I);
     I := filter(B, D, I);
     π := plan(B, I);
     while not empty(π)
             or succeeded(I, B)
             or impossible(I, B)) do
          α := hd(π);
          execute(α);
          π := tail(π);
          get next percept ρ;
          B := brf(B, ρ);
          if reconsider(I, B) then
               D := options(B, I);
               I := filter(B, D, I);
          end-if
          if not sound(π, I, B) then
               π := plan(B, I)
          end-if
     end-while
end-while
```

If π is a plan, then with reference to this pseudo-code, explain the purpose/role of the following components:

(a) The $empty()$ function. **(2 marks)**

(b) The $hd()$ function. **(2 marks)**

(c) The $tail()$ function. **(2 marks)**

(d) The $sound()$ function. **(2 marks)**

(e) The $plan()$ function. **(2 marks)**

(f) 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

An agent has a set of actions Ac, such that $Ac = \{Stack, UnStack, Pickup, PutDown\}$:

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

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

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

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

It also has the following beliefs B_0 regarding the four bricks $\{A, B, C, D\}$, and the intention i:

$Beliefs\ B_0$	$Intention\ i$
$Clear(C)$	$Clear(A)$
$Clear(D)$	$On(A, B)$
$On(C, A)$	$On(B, C)$
$On(D, B)$	$On(C, D)$
$OnTable(A)$	$OnTable(D)$
$OnTable(B)$	

Calculate a plan π that would achieve i, given the beliefs B_0. Draw the environment at the beginning of the plan, and after every time a $Stack$ or $UnStack$ action is performed. **(15 marks)**

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

$$\begin{aligned} a &\rightarrow 6 \\ b &\rightarrow 2 \\ a \wedge b &\rightarrow 4 \\ b \wedge \neg c &\rightarrow -1 \end{aligned}$$

Let ν be the characteristic function defined by these rules. Give the values of the following:

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

(10 marks)

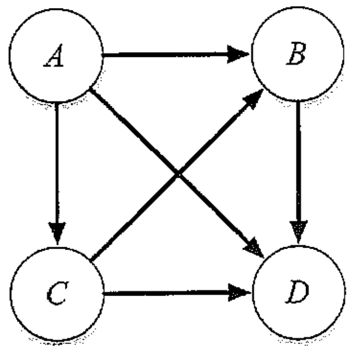
(b) A key issue in coalition formation is that of *stability*. Explain what you understand by this issue, and how the *core* tries to capture stability.

(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) Another key issue in coalition formation is that of *fairly distributing coalitional value*. Explain what you understand by this issue, and how the *Shapley value* tries to capture a fair distribution. In your answer, you should clearly explain the properties that the Shapley value satisfies.

(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 Shapley value.) **(10 marks)**

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



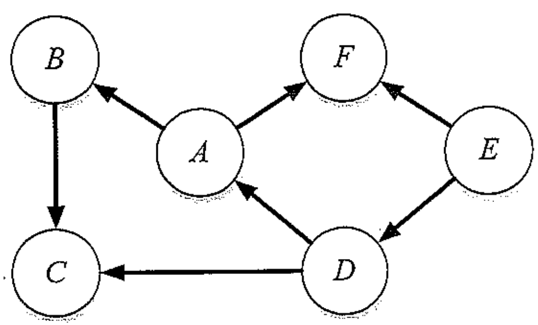
(a) For each of the four candidates, state whether they have a chance of winning in a sequential majority election. Where the answer is "yes", give an example of a linear agenda that would lead to the respective candidate winning.

(8 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 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*.

(2 marks each, for a total of 12 marks)

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5. The following payoff matrix (A) is for the "prisoner's dilemma":

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

The following payoff matrix (B) is for the "stag hunt":

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

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

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

(a) For each of these payoff matrices:

(i) Identify all (pure strategy) Nash Equilibria;

(i) Identify all Pareto optimal outcomes;

(iii) Identify all outcomes that maximise social welfare.

(18 marks)

(b) Cooperation is (provably) the rational choice in the infinitely repeated prisoners dilemma. Is this the case if there are a fixed, finite number of repetitions or rounds? If so, justify your answer; whereas if not, what would be the best strategy, and why? **(7 marks)**