SECOND SEMESTER EXAMINATIONS 2017/18

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. 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)**

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

$$E = \{e_0, e_1, e_2, e_3, e_4, e_5\} \qquad \tau(e_0 \xrightarrow{\alpha_0}) = \{e_1, e_2\} \qquad \tau(e_2 \xrightarrow{\alpha_2}) = \{e_4, e_5\}$$
$$\tau(e_1 \xrightarrow{\alpha_1}) = \{e_3, e_4\} \qquad \tau(e_4 \xrightarrow{\alpha_3}) = \{e_6\}$$

There are two agents, Ag_1 and Ag_2, with respect to this environment:

$$\begin{array}{r|l} Ag_1(e_0) = \alpha_0 & Ag_2(e_0) = \alpha_0 \\ Ag_1(e_1) = \alpha_1 & Ag_2(e_2) = \alpha_2 \\ & Ag_2(e_4) = \alpha_3 \end{array}$$

Assume the utility function and probabilities of the various runs are defined as follows:

$$\begin{array}{r|l} P(e_0 \xrightarrow{\alpha_0} e_1 \mid Ag_1, Env_1) = 0.9 & P(e_0 \xrightarrow{\alpha_0} e_1 \mid Ag_2, Env_1) = 0.2 \\ P(e_0 \xrightarrow{\alpha_0} e_2 \mid Ag_1, Env_1) = 0.1 & P(e_0 \xrightarrow{\alpha_0} e_2 \mid Ag_2, Env_1) = 0.8 \\ P(e_1 \xrightarrow{\alpha_1} e_3 \mid Ag_1, Env_1) = 0.6 & P(e_2 \xrightarrow{\alpha_2} e_4 \mid Ag_2, Env_1) = 0.6 \\ P(e_1 \xrightarrow{\alpha_1} e_4 \mid Ag_1, Env_1) = 0.4 & P(e_2 \xrightarrow{\alpha_2} e_5 \mid Ag_2, Env_1) = 0.4 \\ & P(e_4 \xrightarrow{\alpha_3} e_6 \mid Ag_2, Env_1) = 1.0 \end{array}$$

Assume the utility function u_1 is defined as follows:

$$\begin{array}{r|l} u_1(e_0 \xrightarrow{\alpha_0} e_1) = 4 & u_1(e_0 \xrightarrow{\alpha_0} e_2) = 5 \\ u_1(e_1 \xrightarrow{\alpha_1} e_3) = 8 & u_1(e_1 \xrightarrow{\alpha_1} e_4) = 6 \\ u_1(e_2 \xrightarrow{\alpha_2} e_4) = 3 & u_1(e_2 \xrightarrow{\alpha_2} e_5) = 7 \\ u_1(e_4 \xrightarrow{\alpha_3} e_6) = 2 & \end{array}$$

(d) Given these definitions draw a graph of the possible runs for the two agents Ag_1 and Ag_2 with respect to Env_1. **(4 marks)**

(e) Write down all of the possible runs by either (or both) agents starting from e_0 that satisfy $\mathcal{R}^E = \{e_6\}$ with respect to Env_1. **(1 marks)**

(f) Determine the expected utility of both agents, and explain which agent is optimal with respect to Env_1 and u_1. Include an explanation of your calculations in your solution. **(5 marks)**

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

```
B := B_0;
I := I_0;
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
```

(a) Recall that "*Practical Reasoning = deliberation + means end reasoning*". With reference to the above code, explain what you understand by "deliberation" and "means end reasoning". (**8 marks**)

(b) One of the aims of one of the loops in the above code is to ensure that the agent is committed to *intentions* as long as it is rational to be committed to them. Explain how the loop achieves this. In your answer, be sure to clearly identify the circumstances under which the agent reconsiders its intentions. (**7 marks**)

(c) In the code above, a new percept ρ is acquired, which related to the transduction problem. Describe the transduction problem. (**4 marks**)

A variant of the Blocksworld scenario is represented by an ontology (assuming the closed world assumption) 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

An agent has a set of actions Ac, such that $Ac = \{Swap, Stack, Unstack\}$, with the rules for each action given below:

	$Swap(x, y)$
pre	$Clear(x)$ & $On(x, y)$ & $OnTable(y)$
del	$Clear(x)$ & $On(x, y)$ & $OnTable(y)$
add	$Clear(y)$ & $On(y, x)$ & $OnTable(x)$

	$Stack(x, y)$
pre	$Clear(x)$ & $Clear(y)$ & $OnTable(x)$
del	$Clear(y)$ & $OnTable(x)$
add	$On(x, y)$

	$Unstack(x, y)$
pre	$Clear(x)$ & $On(x, y)$
del	$On(x, y)$
add	$OnTable(x)$ & $Clear(y)$

An agent starts with the Belief B_0, and needs a plan to achieve the intention I, where

$$B_0 = \{Clear(A), Clear(B), On(D, C), OnTable(B), OnTable(C), On(A, D)\}$$

$$I = \{Clear(A), On(C, D), On(B, C), On(A, B), OnTable(D)\}$$

(d) A plan π_1 is proposed to allow the agent to achieve this intention I, from the Belief B_0; however this plan fails:

$$\pi_1 = \{Stack(B, A), Swap(B, A), Swap(D, C)\}$$

With reference to the actions Ac, explain why the above plan (π_1) does not succeed. **(2 marks)**

(e) Identify a valid plan π_2 that makes use of the actions in Ac to achieve the intention I given the initial set of beliefs B_0. **(4 marks)**

3. (a) A multi-agent system can exploit the use of *Social Norms* (i.e. rules of social behaviour) to coordinate activities. Norms can be explicitly designed offline, and then the agents are programmed to follow these norms. Describe the notion of a social law with respect to an environment, and describe an example of a useful social law that is used to coordinate social behaviour of agents within a MAS. (**10 marks**)

(b) Explain and define the solution concept of *pure strategy Nash equilibrium*. Identify with an explanation what is/are the pure strategy Nash Equilibrium outcome(s) in the game "Stag Hunt", defined by the following payoff matrix:

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

(**10 marks**)

(c) The following payoff matrix is for the game of matching pennies:

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

With reference to this payoff matrix, explain the notion of *mixed strategy Nash Equilibrium* and Nash's Theorem. (**5 marks**)

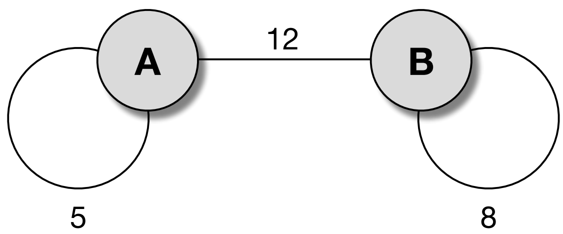
4. (a) In the context of cooperative games, consider the following marginal contribution net:

$$\begin{aligned} a \wedge b \wedge d &\rightarrow 5 \\ a \wedge b &\rightarrow 4 \\ d &\rightarrow 5 \\ a \wedge c \wedge d &\rightarrow 4 \\ d \wedge e &\rightarrow 1 \\ a \wedge c &\rightarrow 2 \end{aligned}$$

Let φ_i denote the Shapley value for agent i. Given these rules, calculate the Shapley value for each of the agents: i.e. φ_a, φ_b, φ_c, φ_d, and φ_e. In each case, justify your answer with respect to the rule or rules of the above marginal contribution net.

(**10 marks**)

(b) Consider the following weighted subgraph representation of a characteristic function:



Let ν be the characteristic function defined by this graph.

(i) Give the values of $\nu(\{a\})$, $\nu(\{b\})$, and $\nu(\{a, b\})$.

(**6 marks**)

(ii) Give an example of a payoff distribution that is in the core of the game, and an example of a payoff distribution that is *not* in the core of the game. In both cases justify your answer.

(**4 marks**)

(c) A Vickrey auction is a *second-price sealed-bid* auction, which has the important characteristic that a bidder's dominant strategy is to bid their true valuation. Explain why this is the case, with reference to what could happen if the bidder bids either more, or less than its true value.

(**5 marks**)

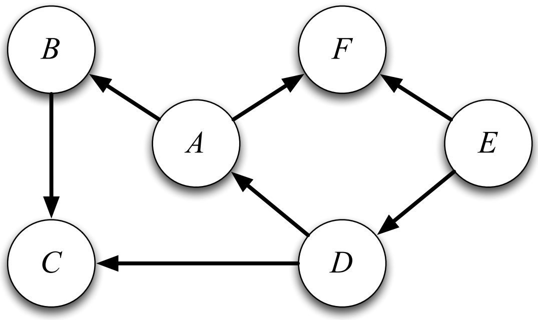
5. In a *Deductive Argumentation* system, two agents each put forward their individual arguments $\alpha_1 = (S_1, p_1)$ and $\alpha_2 = (S_2, p_2)$ respectively, where the support of the arguments is given by S_1, S_2 and the conclusion or premise is given by p_1, p_2.

Explain what is meant by, and in each case, give an example of the following:

(a) A *rebuttal*, i.e. (S_2, p_2) rebuts (S_1, p_1). **(3 marks)**

(b) An *undercut*, i.e. (S_2, p_2) undercuts (S_1, p_1). **(3 marks)**

The following figure shows an *Abstract Argumentation* system.



(c) Calculate the *Conflict-Free* sets of this argumentation system. **(9 marks)**

(d) Calculate the *Admissible* sets of this argumentation system. **(4 marks)**

(e) Determine the *Preferred Extensions* of this argumentation system. **(2 marks)**

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*.

(f) Briefly describe the role of the *Agent Management System*. **(2 marks)**

(g) Briefly describe the role of the *Directory Facilitator*. **(2 marks)**