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UNIVERSITY OF LIVERPOOL

SECOND SEMESTER EXAMINATIONS 2016/17

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. 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 the meanings (and outcomes) of the program constructs:

(i) The $brf(B, \rho)$ function. **(2 marks)**

(ii) The $options(B, I)$ function. **(2 marks)**

(iii) The $filter(B, D, I)$ function. **(2 marks)**

(iv) The $plan(B, I)$ function. **(2 marks)**

(v) The $sound(\pi, I, B)$ function. **(2 marks)**

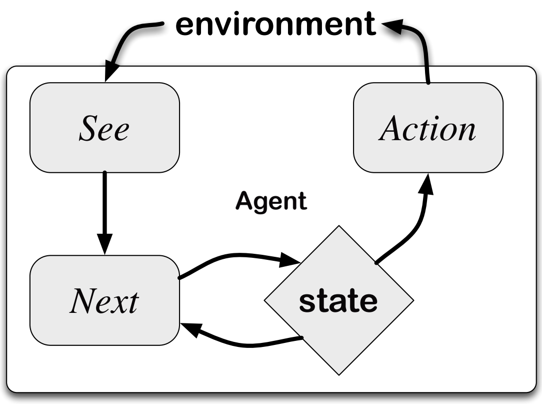
(b) The while loop (lines 9-22) in the above program terminates for each of the following situations. Explain briefly the current scenario (i.e. what could have happened) that could have resulted in each of the termination situations:

(i) $empty(\pi)$ is true, $succeeded(I, B)$ is false, and $impossible(I, B)$ is false. **(2 marks)**

(ii) $empty(\pi)$ is false, $succeeded(I, B)$ is false, and $impossible(I, B)$ is true. **(2 marks)**

(iii) $empty(\pi)$ is false, $succeeded(I, B)$ is true, and $impossible(I, B)$ is false. **(2 marks)**

(c) The diagram below illustrates a simple model of an agent and its components.



With reference to the above diagram, explain the purpose/role of the following functions:

(i) $see : E \mapsto Per$ **(3 marks)**

(ii) $action : I \mapsto Ac$ **(3 marks)**

(iii) $next : I \times Per \mapsto I$ **(3 marks)**

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2. Luc Steels exploited the subsumption architecture to achieve a near-optimal cooperative performance in a simulated *rock gathering problem on Mars*. Several rules were used to determine different behaviours, that would fire in different situations.

(a) Describe four rules that were used to allow agents to explore for and collect rock samples. In each case, describe the pre-conditions, and the resulting action. Ensure that for each rule, you also explain the purpose of the rule.

(**3 marks each, for a total of 12 marks**)

(b) Explain how the use of radioactive particles were used to support *stigmergy*; i.e. the mechanism of implicit communication between agents through changes to the environment. Describe why this was useful in the *rock gathering problem on Mars*.

(**4 marks**)

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

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

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:

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

(c) 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**)

(d) 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**)

3. 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:

(a) Upper Ontology (**3 marks**)

(b) Domain Ontology (**3 marks**)

(c) Application Ontology (**3 marks**)

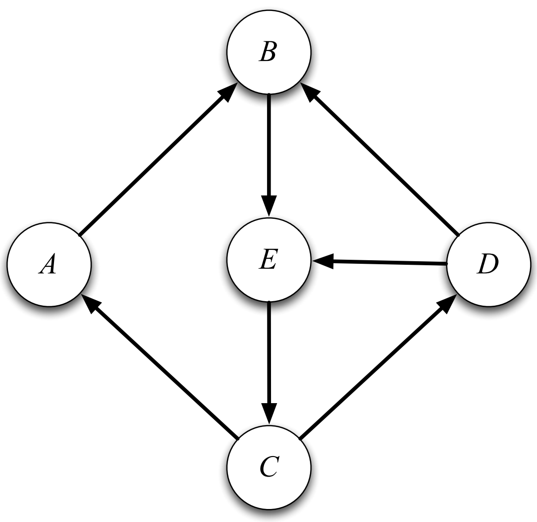
In his 1969 book *"Speech Acts: an Essay' in the Philosophy of Language"*, John Searle identified a number of different speech acts, some of which have informed research into agent communication languages such as KQML and FIPA ACL. In each of the questions below, give a brief description of the speech act category and give an example for each. The example can be given in words, and does not have to be an actual KQML or FIPA ACL performative.

(d) Representatives (**2 marks**)

(e) Directives (**2 marks**)

(f) Commissives (**2 marks**)

The following figure shows an abstract argumentation system.



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

(**2 marks each, for a total of 10 marks**)

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4. Seventeen friends make plans to go to a restaurant, and decide to use a Social Choice Function to decide on a single cuisine. Each friend can be considered as an agent, such that we have $n = 17$ agents. The set of outcomes can be defined as

$$omega = \{\text{french, italian, mexican, pan-asian}\}$$

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

Votes	5	3	5	4
First Choice	mexican	french	pan-asian	italian
Second Choice	italian	pan-asian	mexican	french
Third Choice	pan-asian	italian	italian	mexican
Forth Choice	french	mexican	french	pan-asian

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

(a) Borda count **(5 marks)**

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

The *Monotonic Concession Protocol* was proposed as a means of allowing two agents to agree upon a deal for some good. The negotiation proceeds in rounds, starting with round $u = 1$.

(c) Describe each of the five rules of this protocol.

(2 marks for each rule, for a total of 10 marks)

The Zeuthen strategy for negotiation answers two questions that must be answered on any given round of negotiation, which are stated below. For each question, explain the answers that the Zeuthen strategy provides:

(d) *Who should concede?* **(3 marks)**

(e) *How much should they concede?* **(2 marks)**

5. Consider the coalition game with agents $Ag = \{a, b, c\}$ and characteristic function ν defined by:

$$\begin{aligned}
\nu\{\varnothing\} &= 0 \\
\nu\{a\} &= 12 \\
\nu\{b\} &= 18 \\
\nu\{c\} &= 6 \\
\nu\{a, b\} &= 60 \\
u\{b, c\} &= 48 \\
\nu\{a, c\} &= 72 \\
\nu\{a, b, c\} &= 120
\end{aligned}$$

(a) 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.

(**5 marks for each agent, for a total of 15 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 of chicken, defined by the following payoff matrix:

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

(**10 marks**)