| PAPER CODE NO. **COMP510** | EXAMINER : Michael Wooldridge<br>DEPARTMENT : Computer Science Tel. No. 4-3670 |
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THE UNIVERSITY
*of* LIVERPOOL

# MAY 2004 EXAMINATIONS

Bachelor of Science : Year 3
Master of Science : Year 1

# Multiagent Systems

**TIME ALLOWED : $2\frac{1}{2}$ hours**

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**INSTRUCTIONS TO CANDIDATES**

This paper contains **five** questions in total. Answer **any four** questions only.

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

## Question 1

a) The issue of telling an agent what to do (without telling it how to do it) is a central problem in multiagent systems. A number of approaches to this problem have been proposed, chief among them being the following:

- utility functions over states;
- utility functions over runs;
- predicates over runs;
- achievement tasks;
- maintenance tasks.

Explain what you understand by each of these approaches, making clear the relative advantages and disadvantages of each and how these approaches relate to one-another. Illustrate your answer with examples as appropriate.

[5 marks]

b) Some researchers have argued that the notion of *bounded optimality* is a more appropriate measure of optimality than that of simply maximising expected utility. Present these arguments as you understand them, and formally define the notion of a bounded optimal agent.

[5 marks]

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

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

There are just two agents possible 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:

$$P(e_0 \xrightarrow{\alpha_0} e_1 \mid Ag_1, Env_1) = 0.02$$
$$P(e_0 \xrightarrow{\alpha_0} e_2 \mid Ag_1, Env_1) = 0.95$$
$$P(e_0 \xrightarrow{\alpha_0} e_3 \mid Ag_1, Env_1) = 0.03$$
$$P(e_0 \xrightarrow{\alpha_1} e_4 \mid Ag_2, Env_1) = 0.2$$
$$P(e_0 \xrightarrow{\alpha_1} e_5 \mid Ag_2, Env_1) = 0.2$$
$$P(e_0 \xrightarrow{\alpha_1} e_6 \mid Ag_2, Env_1) = 0.6$$

Finally, assume the utility function $u_1$ is defined as follows:

$$u_1(e_0 \xrightarrow{\alpha_0} e_1) = 70$$
$$u_1(e_0 \xrightarrow{\alpha_0} e_2) = 1$$
$$u_1(e_0 \xrightarrow{\alpha_0} e_3) = 80$$
$$u_1(e_0 \xrightarrow{\alpha_1} e_4) = 4$$
$$u_1(e_0 \xrightarrow{\alpha_1} e_5) = 5$$
$$u_1(e_0 \xrightarrow{\alpha_1} e_6) = 3$$

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 $u_1$.

[15 marks]

## Question 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
```

With reference to this pseudo-code, explain the purpose/role of the following components:

a) The variables $B$, $D$, and $I$. [6 marks]

b) The percept $\rho$. [2 marks]

c) The $brf(\ldots)$ function. [2 marks]

d) The $options(\ldots)$ function. [2 marks]

e) The $filter(\ldots)$ function. [2 marks]

f) The $plan(\ldots)$ function. [2 marks]

g) The $sound(\ldots)$ function. [2 marks]

h) The $succeeded(\ldots)$ and $impossible(\ldots)$ functions. [2 marks]

i) The $reconsider(\ldots)$ function — in your answer to this part of the question, you should make clear what properties this function should have, and the situations in which it can be assumed to be functioning correctly.

[5 marks]

**Question 3**

a) Explain, with the aid of examples where appropriate, what you understand by *task sharing* and *result sharing* in the context of cooperative distributed problem solving systems.

[5 marks]

b) The CONTRACT NET protocol is the most widely studied protocol in cooperative distributed problem solving. Describe the main stages of the contract net, making clear in your answer how FIPA performatives that might be used to implement these stages.

[10 marks]

c) The following is a short KQML/KIF dialogue between two agents, with respect to an engineering domain.

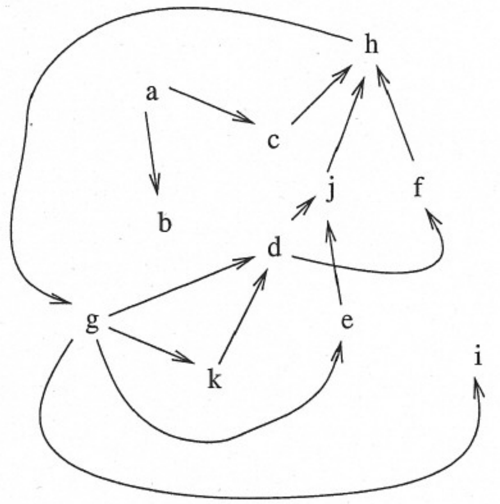
```
(stream-about
      :sender A
      :receiver B
      :language KIF
      :ontology motors
      :reply-with q1
      :content m1
)
(tell
      :sender B
      :receiver A
      :in-reply-to q1
      :content (= (torque m1) (scalar 12 kgf))
)
(tell
      :sender B
      :receiver A
      :in-reply-to q1
      :content (= (status m1) normal)
)
(eos
      :sender B
      :receiver A
      :in-reply-to q1
)
```

Give an interpretation of this dialogue, making clear in your answer the role that the various components of the messages are playing.

[10 marks]

**Question 4**

a) The following figure shows an abstract argument system.




Explain the status of the following arguments, justifying your answer in each case:

$a \quad b \quad c \quad d \quad e \quad f \quad g \quad h \quad i \quad j$

[2 marks each]

b) Logic-based argumentation and negotiation provide two related but distinct approaches by which agents can reach agreements on matters of common interest in multiagent systems. Compare and contrast the two approaches, ensuring in your answer that you make clear the applications to which you believe the approaches are best suited.

[5 marks]

**Question 5**

Consider the following payoff matrices.
Payoff matrix A:

| | | *i* defect | *i* coop |
|---|---|---|---|
| *j* | defect | 2<br>2 | 1<br>4 |
| *j* | coop | 4<br>1 | 3<br>3 |

Payoff matrix B:

| | | *i* defect | *i* coop |
|---|---|---|---|
| *j* | defect | 1<br>1 | 2<br>4 |
| *j* | coop | 4<br>2 | 3<br>3 |

With reference to these payoff matrices:

a) Define the notion of a Nash equilibrium strategy pair, explain why the concept of Nash equilibrium strategies is so important, and identify with justification which (if any) strategy pairs in these payoff matrices are in Nash equilibrium.

[10 marks]

b) Define the notion of a Pareto optimal outcome, explain why the concept of Pareto optimal outcomes is so important, and identify with justification which (if any) outcomes in these payoff matrices are Pareto optimal.

[10 marks]

c) Define what it means for an outcome to maximise social welfare, and identify with justification which outcome(s) in these payoff matrices maximise social welfare.

[5 marks]