SECOND SEMESTER 2010/11 EXAMINATIONS

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).
Question 1

a) 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:

$$P(e_0 \xrightarrow{\alpha_0} e_1 | Ag_1, Env_1) = 0.7$$

$$P(e_0 \xrightarrow{\alpha_0} e_2 | Ag_1, Env_1) = 0.2$$

$$P(e_0 \xrightarrow{\alpha_0} e_3 | Ag_1, Env_1) = 0.1$$

$$P(e_0 \xrightarrow{\alpha_1} e_4 | Ag_2, Env_1) = 0.6$$

$$P(e_0 \xrightarrow{\alpha_1} e_5 | Ag_2, Env_1) = 0.3$$

$$P(e_0 \xrightarrow{\alpha_1} e_6 | Ag_2, Env_1) = 0.1$$

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

$$u_1(e_0 \xrightarrow{\alpha_0} e_1) = 10$$

$$u_1(e_0 \xrightarrow{\alpha_0} e_2) = 6$$

$$u_1(e_0 \xrightarrow{\alpha_0} e_3) = 5$$

$$u_1(e_0 \xrightarrow{\alpha_1} e_4) = 12$$

$$u_1(e_0 \xrightarrow{\alpha_1} e_5) = 3$$

$$u_1(e_0 \xrightarrow{\alpha_1} e_6) = 4$$

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 1 continued…]

b) According to McCarthy, when is it *legitimate* to use the intentional stance to explain and predict the behaviour of machines? [5 marks]

c) According to McCarthy, when is it *useful* to use the intentional stance to explain and predict the behaviour of machines? [5 marks]
Question 2

The following pseudo-code defines a control loop for a practical reasoning (“BDI”) agent.

1. \( B := B_0; \quad I := I_0; \)
2. while true do
   3. get next percept \( \rho; \)
   4. \( B := \text{brf}(B, \rho); \)
   5. \( D := \text{options}(B, I); \)
   6. \( I := \text{filter}(B, D, I); \)
   7. \( \pi := \text{plan}(B, I); \)
   8. while not (empty(\( \pi \)) or succeeded(\( I, B \)) or impossible(\( I, B \))) do
      9. \( \alpha := \text{hd}(\pi); \)
      10. execute(\( \alpha; \)
      11. \( \pi := \text{tail}(\pi); \)
      12. get next percept \( \rho; \)
      13. \( B := \text{brf}(B, \rho); \)
      14. if reconsider(\( I, B \)) then
            15. \( D := \text{options}(B, I); \)
            16. \( I := \text{filter}(B, D, I); \)
      end-if
      17. if not sound(\( \pi, I, B \)) then
            18. \( \pi := \text{plan}(B, I) \)
      end-if
   end-while
21. end-while
22. 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 \( \text{brf}(\ldots) \) function.  
   [2 marks]

d) The \( \text{options}(\ldots) \) function.  
   [2 marks]

e) The \( \text{filter}(\ldots) \) function.  
   [2 marks]

f) The \( \text{plan}(\ldots) \) function.  
   [2 marks]

g) The \( \text{sound}(\ldots) \) function.  
   [2 marks]

h) The \( \text{succeeded}(\ldots) \) and \( \text{impossible}(\ldots) \) functions.  
   [2 marks]

i) The \( \text{reconsider}(\ldots) \) 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

In the answer to this question, you may wish to use some of the notation used in Question 1.

a) It has been argued that the multi-agent systems paradigm emerged from five ongoing trends in computing. Explain what you understand these trends to be. [5 marks]

b) Explain what is meant by a predicate task specification, and how such a specification relates to utility functions over runs. [5 marks]

c) Explain what is meant by an achievement goal. [5 marks]

d) Explain what is meant by a maintenance goal. [5 marks]

e) Two key problems that arise in deductive/symbolic agent architectures are transduction and representation/reasoning. Explain what you understand by these problems. [5 marks]
Question 4

a) “If we choose voting protocols that are hard to manipulate, then computational complexity can come to the rescue of social choice theory.” Explain and critically assess this argument, highlighting any practical weaknesses in it.

[15 marks]

b) Explain with the aid of examples how it is possible for an unscrupulous election organiser to manipulate the agenda in sequential pairwise majority elections in order to favour a particular candidate.

[10 marks]
Question 5

The following payoff matrix (A) is for the “prisoner’s dilemma”.

<table>
<thead>
<tr>
<th></th>
<th>defect</th>
<th>coop</th>
</tr>
</thead>
<tbody>
<tr>
<td>defect</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>coop</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

The following payoff matrix (B) is for “matching pennies”.

<table>
<thead>
<tr>
<th></th>
<th>heads</th>
<th>tails</th>
</tr>
</thead>
<tbody>
<tr>
<td>heads</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>tails</td>
<td>1</td>
<td>-1</td>
</tr>
</tbody>
</table>

The following payoff matrix (C) is for “game of chicken”.

<table>
<thead>
<tr>
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<th>defect</th>
<th>coop</th>
</tr>
</thead>
<tbody>
<tr>
<td>defect</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>coop</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

a) For each of these payoff matrices:

i) identify all (pure strategy) Nash equilibria;

ii) identify all Pareto optimal outcomes;

iii) identify all outcomes that maximise social welfare.

[18 marks]

b) “Program equilibria make cooperation possible in the one-shot prisoner’s dilemma”. Explain and critically assess this statement.

[7 marks]