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COMP310

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UNIVERSITY OF LIVERPOOL

SECOND SEMESTER EXAMINATIONS 2015/16

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).

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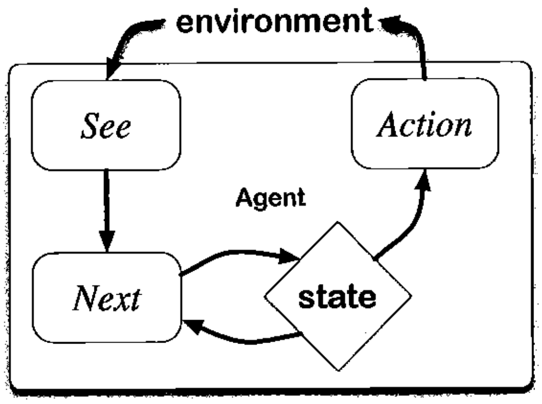
1. The diagram below illustrates a simple model of an agent and its components.



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

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

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

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

A classical approach to building agents is to view them as a particular type of knowledge-based system based on *symbolic AI*. Given this, a deliberative agent is one that contains an explicitly represented, symbolic model of the world, and that makes decisions via symbolic reasoning.

(d) Describe the transduction problem, and identify which of the functions in the diagram (at the start of Question 1) that it relates to. **(3 marks)**

(e) Describe the representation/reasoning problem, and identify which of the functions in the diagram (at the start of Question 1) that it relates to. **(3 marks)**

The rest of Question 1 is on the next page.

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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:

$$\begin{array}{r|l} P(e_0 \xrightarrow{\alpha_0} e_1 \mid Ag_1, Env_1) = 0.8 & P(e_0 \xrightarrow{\alpha_0} e_1 \mid Ag_2, Env_1) = 0.3 \\ P(e_0 \xrightarrow{\alpha_0} e_2 \mid Ag_1, Env_1) = 0.2 & P(e_0 \xrightarrow{\alpha_0} e_2 \mid Ag_2, Env_1) = 0.7 \\ P(e_1 \xrightarrow{\alpha_1} e_3 \mid Ag_1, Env_1) = 0.5 & P(e_2 \xrightarrow{\alpha_2} e_4 \mid Ag_2, Env_1) = 0.6 \\ P(e_1 \xrightarrow{\alpha_1} e_4 \mid Ag_1, Env_1) = 0.5 & P(e_2 \xrightarrow{\alpha_2} e_5 \mid Ag_2, Env_1) = 0.4 \\ & P(e_4 \xrightarrow{\alpha_3} e_6 \mid Ag_2, Env_1) = 1.0 \end{array}$$

Assume the utility function u_1 is defined as follows:

$$\begin{array}{r|l} u_1(e_0 \xrightarrow{\alpha_0} e_1) = 4 & u_1(e_0 \xrightarrow{\alpha_0} e_2) = 5 \\ u_1(e_1 \xrightarrow{\alpha_1} e_3) = 9 & u_1(e_1 \xrightarrow{\alpha_1} e_4) = 8 \\ u_1(e_2 \xrightarrow{\alpha_2} e_4) = 3 & u_1(e_2 \xrightarrow{\alpha_2} e_5) = 6 \\ u_1(e_4 \xrightarrow{\alpha_3} e_6) = 2 & \end{array}$$

(f) 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)**

(g) 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)**

(h) 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)**

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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 three rules that were used to allow agents to explore for, and collect rock samples. In each case, describe what the pre-conditions are, and then what action is performed. Ensure that for each rule, you also explain the purpose of the rule.

(9 marks, 3 for each rule)

(b) Explain how the use of radioactive particles were used to support implicit communication between agents, and describe why this was useful in the *rock gathering problem on Mars.* **(4 marks)**

A variant of 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
$ArmEmpty$	arm is not holding any object

An agent has a set of actions Ac , such that $Ac = \{Grab, Build, Drop, Demolish\}$ given below. However, due to mistakes made by the agent developer, there may be one or more errors in the action definitions.

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

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

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

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

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For each of the following planning problems given below, determine if the intention I is possible given Ac and the initial beliefs B_0 (assuming the closed world assumption), and either: if I is possible, give the shortest plan π that achieves it from B_0; otherwise if I is not possible (i.e. the plan is empty, $\pi = \emptyset$) , explain why not.

(c) Given $\langle B_0, Ac, I\rangle$ below, determine the shortest π, or explain why $\pi = \emptyset$.

$$\begin{aligned} Beliefs\ B_0 = \{ \ & ArmEmpty, Clear(A), OnTable(A), \\ & Clear(B), OnTable(B), Clear(C), OnTable(C) \ \} \\ Intention\ I = \{ \ & ArmEmpty, Clear(A), On(A,B), \\ & On(B,C), OnTable(C) \ \} \end{aligned}$$

(4 mark)

(d) Given $\langle B_0, Ac, I\rangle$ below, determine the shortest π, or explain why $\pi = \emptyset$.

$$\begin{aligned} Beliefs\ B_0 = \{ \ & ArmEmpty, OnTable(A), OnTable(B), Clear(B) \\ & On(C,A), Clear(C) \ \} \\ Intention\ I = \{ \ & ArmEmpty, Clear(A), On(A,B), OnTable(B), \\ & OnTable(C), Clear(C) \ \} \end{aligned}$$

(4 mark)

(e) Given $\langle B_0, Ac, I\rangle$ below, determine the shortest π, or explain why $\pi = \emptyset$.

$$\begin{aligned} Beliefs\ B_0 = \{ \ & Holding(A), On(B,C), OnTable(C), \\ & OnTable(D), Clear(D) \ \} \\ Intention\ I = \{ \ & Holding(A), On(B,C), OnTable(C), \\ & On(D,B), Clear(D) \ \} \end{aligned}$$

(4 mark)

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3. 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.

   (a) Representatives **(2 marks)**

   (b) Directives **(2 marks)**

   (c) Commisives **(2 marks)**

   (d) Expressives **(2 marks)**

   (e) Declarations **(2 marks)**

   A well known task-sharing protocol for task allocation that utilises speech acts is the Contract Net Protocol, which is loosely based on a similar process used in business to tender contracts for tasks.

   (f) Briefly summarise the five stages involved in the Contract Net Protocol. **(5 marks)**

   In the context of cooperative games, consider the following marginal contribution net:

$$
\begin{aligned}
a \wedge b \wedge d &\rightarrow 7\\
a \wedge b &\rightarrow 3\\
d &\rightarrow 5\\
a \wedge c \wedge d &\rightarrow 4\\
a \wedge c &\rightarrow 2
\end{aligned}
$$

   Let ν be the characteristic function defined by these rules. Give the values of the following, and in each case, justify your answer with respect to the rule or rules of the above marginal contribution net:

   (g) $\nu(\{a\})$ **(2 marks)**

   (h) $\nu(\{a, c\})$ **(2 marks)**

   (i) $\nu(\{b, d\})$ **(2 marks)**

   (j) $\nu(\{a, c, d\})$ **(2 marks)**

   (k) $\nu(\{a, b, c, d\})$ **(2 marks)**

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4. Combinatorial auctions allow bidders to bid for bundles of goods. In this context, and assuming that we use XOR bids, the following bid is made:

$$B_i = (\{a, b\}, 5)\ XOR\ \{e, f, g\}, 2)\ XOR\ (\{e\}, 2)\ XOR\ (\{c, d, e\}, 4)$$

Let v_{B_i} be a bundle of goods on offer. For each of the following bundles, determine if the bid B_i satisfies the bundle of goods, and state what would be paid for that bundle.

(a) $v_{B_i}(\{e\})$ **(2 marks)**

(b) $v_{B_i}(\{e, f\})$ **(2 marks)**

(c) $v_{B_i}(\{c, d, f, g\})$ **(2 marks)**

(d) $v_{B_i}(\{c, d, e, f, g\})$ **(2 marks)**

(e) $v_{B_i}(\{a, b, c, d, e, f, g\})$ **(2 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 $u = 1$.

(f) Describe each of the five rules of this protocol. **(5 marks)**

(g) The Zeuthen strategy for negotiation answers two questions that must be answered on any given round of negotiation: *who should concede?* and *how much should they concede?* Explain the answers that the Zeuthen strategy provides to these questions. **(10 marks)**

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

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

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

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

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

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

For each of these payoff matrices:

(a) Identify all (pure strategy) Nash Equilibria; **(3 marks)**

(b) Identify all Pareto optimal outcomes; **(3 marks)**

(c) Identify all outcomes that maximise social welfare. **(3 marks)**

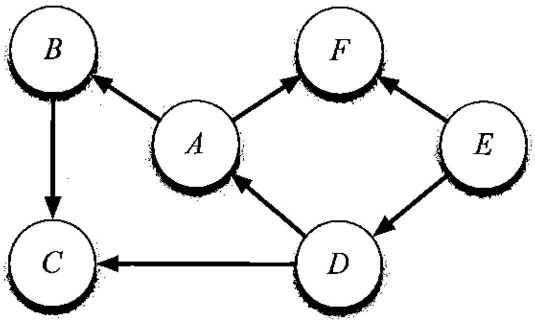
In a *Deductive Argumentation* system, two agents each put forward their individual arguments $\alpha_1 = (S_1, p_1)$ and $\alpha_2 = (S_2, p_2)$ respectively, where the support of the arguments is given by S_1, S_2 and the conclusion or premise is given by p_1, p_2.

Explain what is meant (and in each, give an example of):

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

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

The following figure shows an *Abstract Argumentation* system.



(f) Calculate the *Conflict-Free* sets of this argumentation system. **(4 marks)**

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

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