Agent-Based Systems Classroom and Optional Exercises

Semester 2, 2016/17 session

Week 1 material

C1 For which of the following applications would an agent-based solution be appropriate?

(a) A word processing software suite

(b) An MP3 player with wireless networking capabilities

(c) An automated monitoring system for a national railway network

Consider, for each application, a single-agent and a multiagent solution separately. Give reasons for your answer.

C2 Imagine you are building a multiagent system for computing integer-valued polynomials of the form $f(x) = a_k x^k + a_{k-1} x^{k-1} + \ldots + a_1 x + a_0$ given the following specification:

- The environment provides (successively, in unknown intervals) a number of integer values for x and expects to obtain the result $f(x)$; this can be sent to a designated output port by any agent
- There are four types of agents:
  - "Addition agents" which can add two given integers and return the output
  - "Multiplication agents" which can multiply two given integers and return the output
  - "Storage agents" which can hold the value of an integer (note that addition/multiplication agents compute the output and cannot store the results)
  - A single "manager" agent who can create arbitrary numbers of agents of the other types at runtime

  All agent types can be made to obtain their inputs or output their outputs to one or multiple other agents.
- All agents can communicate with each other by sending integer values back and forth
- The manager agent holds the coefficient values $\{a_1, \ldots a_k\}$ initially and receives input values for x

(a) Suggest a tentative MAS design for this system, clarifying how many agents you require of which type, when they are created, how they communicate, etc.

(b) Describe (i) the characteristics of the environment of the system and (ii) the agents in the system in terms of autonomy, reactiveness, proactiveness and social ability

(c) Write a pseudo-code version of the "traditional" (non-agent) function for computing such polynomials. In which way does it differ from the MAS design? Which piece of software would you prefer, the agent-based or the "traditional" one? Why?

C3 Prove or refute the following statemets:

(a) For every standard agent, there is a behaviourally equivalent purely reactive agent.

(b) For every purely reactive agent, there is a behaviourally equivalent standard agent.

C4 The game of rock-paper-scissors is a single-shot two-player game in which each agent can pick from either of three moves R, P and S simultaneously. The result is evaluated using the following rules:

- P beats R
- R beats S
- S beats P
- all other combinations result in a tie

Assume our opponent (the "environment") plays P with probability 0.4, S with probability 0.5, and R with probability 0.1.

(a) Specify an *optimal* (stochastic) agent for this problem according to the MEU criterion given that the utility for losing the game is -1 and the utility for winning is $+1$, 0 for a tie.

(b) Can you generalise the result for *any* opponent strategy rather than the one defined in part (a)?

O1 The "autonomy dilemma", i.e. the tension between a desire to delegate complex tasks to (semi-)autonomous agents and the need to control software systems is one of the key philosophical problems in the field of intelligent agents. Discuss this problem considering the following examples:

(a) Firearms, while usually not very autonomous, have caused a lot of harm in human history. Do you think making them autonomous would reduce or increase the risks associated with them?

(b) Is it justified for humans to be more uncomfortable with using autonomous (rather than conventional) agent-based systems for safety-critical applications, e.g. control of a nuclear power plant?

(c) Imagine an intelligent e-mail assistant capable of learning from experience which emails you never read deleted them from your inbox permanently to save you from the pain of having to deal with them. Would you agree to use such an application? Why (not)?

O2 Prove or refute the following statements:

(a) For every state-based agent there is behaviourally equivalent standard agent.

(b) For every standard agent there is behaviourally equivalent state-based agent.

(c) Every utility function defined over runs can be expressed by a utility function defined over states.

(d) Every utility function defined over states can be expressed by a utility function defined over runs.

Week 2 material

C5 The following specification describes the famous "Snow White" example in Concurrent MetateM:

$$
\begin{aligned}
\mathsf{SnowWhite(ask)[give]} :& \\
\circledcirc ask(x) &\Rightarrow \Diamond give(x) \\
give(x) \wedge give(y) &\Rightarrow (x = y) \\
\mathsf{eager(give)[ask]} :& \\
start &\Rightarrow ask(eager) \\
\circledcirc give(eager) &\Rightarrow ask(eager) \\
\mathsf{greedy(give)[ask]} :& \\
start &\Rightarrow \Box ask(greedy) \\
\mathsf{courteous(give)[ask]} :& \\
((\neg ask(courteous)\ \mathcal{S}\ give(eager))\wedge& \\
(\neg ask(courteous)\ \mathcal{S}\ give(greedy))) &\Rightarrow ask(courteous) \\
\mathsf{shy(give)[ask]} :& \\
start &\Rightarrow \Diamond ask(shy) \\
\circledcirc ask(x) &\Rightarrow \neg ask(shy) \\
\circledcirc give(shy) &\Rightarrow \Diamond ask(shy)
\end{aligned}
$$

Describe what the programme does and trace its operation in a table for the first three time steps. For reference, the following table summarises the MetateM operators:

$\bigcirc\varphi$	φ is true tomorrow
$\circledcirc\varphi$	φ was true yesterday
$\Diamond\varphi$	φ now or at some point in the future
$\Box\varphi$	φ now and at all points in the future
$\blacklozenge\varphi$	φ was true sometimes in the past
$\blacksquare\varphi$	φ was always true in the past
$\varphi\,\mathcal{U}\,\psi$	ψ some time in the future φ until then
$\varphi\,\mathcal{S}\,\psi$	ψ some time in the past, φ since then (but not now)
$\varphi\mathcal{U}\psi$	ψ was true unless φ was true in the past
$\varphi\,\mathcal{Z}\,\psi$	like " $\mathcal{S}$ " but φ may have never become true

C6 Suggest a compact and elegant decision making algorithm for the vacuum world using first-order logic that works for arbitrary grid sizes. You can use the usual quantifiers $\exists$ and $\forall$, equality $=$, integers and normal operations on them as well as a constant S which denotes the size of the grid.

C7 The Advanced Thermostat System: Assume a heater control system controls a living room and a bedroom area, and is equipped with

- separate thermostats and heater units for both rooms
- timer clocks that allow the thermostat settings to be overruled at certain times (by binary "on"/"off" settings) and also time to be sensed
- motions sensors to note whether people are present in the room

Your task is to build an intelligent BDI-based agent using the control loop discussed in the lecture:

Practical Reasoning Agent Control Loop

$B \leftarrow B_0$; $I \leftarrow I_0$; /* initialisation */
while $true$ do
    get next percept ρ through $see(\ldots)$ function
    $B \leftarrow brf(B, \rho)$; $D \leftarrow options(B, I)$; $I \leftarrow filter(B, D, I)$;
    $\pi \leftarrow plan(B, I, Ac)$;
    while not ($empty(\pi)$ or $succeeded(I, B)$ or $impossible(I, B)$) do
        $\alpha \leftarrow head(\pi)$;
        $execute(\alpha)$;
        $\pi \leftarrow tail(\pi)$;
        get next percept ρ though $see(\ldots)$ function
        $B \leftarrow brf(B, \rho)$;
        if $reconsider(I, B)$ then
            $D \leftarrow options(B, I)$; $I \leftarrow filter(B, D, I)$
        if not $sound(\pi, I, B)$ then
            $\pi \leftarrow plan(B, I, Ac)$
    end-while
end-while

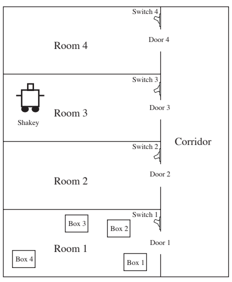
For complex actions you can assume a plan library that will return a sequence of actions to achieve any achievable goal from any given initial state.

(a) Design a language for describing the advanced thermostat world formally in terms of percepts, actions, and beliefs

(b) Suggest a suitable agent design by formally defining the brf, $options$, $filter$ and $reconsider$ functions

(c) For a sequence of percepts of your choice of a few steps, sketch the operation of your system by tracing the workings of the BDI control loop using the functions you have designed

O3 Shakey the robot was the application for which the STRIPS language was originally developed. The figure below shows a version of Shakey's world consisting of four rooms and a corridor. Each room has a door and light switch. Shakey can move from place to place, push movable objects, climb on (and down from) rigid objects and turn light switches on and off (actually the real Shakey couldn't, but the planner can handle all these actions). Shakey needs to climb on a box to turn a light switch, and we assume that all rooms are connected by doors which belong to both rooms.



(a) Develop a logical language for describing Shakey's world
(b) Describe Shakey's actions by appropriate action schemata
(c) Formally describe the initial state shown in the figure above
(d) Construct a plan for Shakey to get Box_2 into $Room_2$ from this initial state

O4 Formally define the function $new : D \times Per \rightarrow D$ that updates the agent's knowledge base for the vacuum-world example (using a schematic tabular representation or pseudo-code, if desired).

Week 3 material

C8 Consider an InteRRaP-based design for a multiagent system composed for building a house, consisting of a builder, an architect, and a house owner agent. Describe informally how you would design the layers of each agent and discuss the issues that arise in the process with particular emphasis on the issue of balancing deliberative and reactive behaviour.

C9 Give an informal definition of the semantics of the following speech acts in terms of the capabilities and mental states of the participating agents:

- $reject(A, B, \varphi)$: A indicates to B that it does not accept that φ is a valid statement
- $refuse(A, B, \alpha)$: A indicates to B that it is not going to perform action α

Distinguish between two different cases: (i) if the two messages are supposed to be used as responses to some request, and (ii) if they can be "standalone" statements.

O5 Design a solution for the vacuum-world example following Brooks' subsumption architecture. Identify how the design needs to change to allow an additional action to charge the robot at the home location whenever it runs low on power. Discuss how this design compares with the design based on deductive reasoning.

O6 Consider the following FIPA protocol diagram for the Brokering Protocol:

(a) Explain its purpose and describe what the admissible message sequences look like that it generates.
(b) Describe any problems that could arise during execution of this protocol.
(c) Discuss the relationship between such a protocol and the process of (planning-based) means-ends reasoning in agent architectures.

Week 4 material

C10 The RoboCup Rescue web site gives the following summary description of the domain:

> RoboCupRescue is a new practical domain of RoboCup. Its main purpose is to provide emergency decision support by integration of disaster information, prediction, planning, and human interface. A generic urban disaster simulation environment is constructed on network computers. Heterogeneous intelligent agents such as fire fighters, commanders, victims, volunteers, etc. conduct search and rescue activities in this virtual disaster world. Real-world interfaces such as helicopter image synchronizes the virtuality and the reality by sensing data. Mission-critical human interfaces such as PDA support disaster managers, disaster relief brigades, residents and volunteers to decide their action to minimize the disaster damage.

The (publicly available RoboCupRescue Simulator) prototype includes four disaster simulator components:

(a) A building collapse simulator based on real earthquake data of relation of ground surface acceleration, structure and age with destruction level.
(b) A road blockage simulator using real data about relation the of seismic scale and street width with the probability of road obstruction.
(c) A fire spread simulator using complex models to simulate combustion, propagation, ignition and extinguishing process models.
(d) A traffic simulator which uses a rule-based micro-simulation method of complex systems considering road width, number of lanes, footpath width, traffic signals, etc.

Using basic sensing (see, hear, listen (for broadcasts)) and action (move, say, tell, extinguish, stretch, rescue, load/unload, clear) abilities, the following class of agents are provided by the simulator:

(a) Moving agents: civilian, fire-fighter, rescuer, police
(b) Static agents: fire station, police station, hospital, refuge, etc.

Consider the RoboCup Rescue MAS and the problem of designing global coordination mechanisms, which would you suggest for each type of inter-group/inter-agent interaction from the following list (under which circumstances):

- Teamwork-based cooperative distributed problem-solving based on joint intentions
- Generalised Partial Global Planning with blackboard-based communication
- Norms and social laws, enforced by (trustable, empowered) external authorities
- Mutual modelling supported by learning to improve models of others

Explain how you would use the suggested method in a concrete way, and discuss its advantages and disadvantages.

C11 You are given the following payoff matrices for two-player normal-form (matrix) games:

G1 2 / 1	D	C
D	(3,3)	(2,4)
C	(1,1)	(4,2)

G2 2 / 1	D	C
D	(-1,-1)	(1,2)
C	(2,1)	(-1,-1)

G3 2 / 1	D	C
D	(3,3)	(0,2)
C	(2,0)	(2,2)

G4 2 / 1	D	C
D	(2,-2)	(-1,1)
C	(-1,1)	(3,-3)

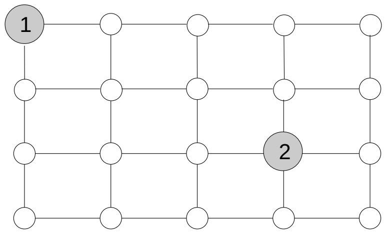
For each of these games

(a) describe the nature of the decision problem represented by it,

(b) identify best-response and dominant strategies for both players,

(c) try to determine its dominant-strategy/Nash equilibria.

O7 In a "trainworld", agents (denoted by 1 and 2 in the figure below) move across a grid-like map of railway connections in any direction, and can perceive the presence of another train in **all nodes around their current position** (3 nodes in the case of agent 1 and 8 nodes in the case of agent 2 in the grid below):



Assuming that the focal states are *all* states in this environment (i.e. any train is in any location), design a useful social law that avoids trains crashing into each other in this environment. You may assume that the agents are not at the same location initially.

Hints: Being stubborn about choice of direction may be useful. Avoiding crashes may justify detours or delays.

O8 Define formally the concept of mixed-strategy Nash equilibria for n-player normal-form games.

Week 5 material

C12 Consider the politics in the UK example from the lecture: $\Omega = \{\omega_L, \omega_D, \omega_C\}$, where ω_L represents the Labour Party, ω_D the Liberal Democrats and ω_C the Conservative Party. Voters have the following preferences:

- 43% of $|Ag|$ are left-wing voters: $\omega_L \succ \omega_D \succ \omega_C$
- 12% of $|Ag|$ are centre-left voters: $\omega_D \succ \omega_L \succ \omega_C$
- 45% of $|Ag|$ are right-wing voters: $\omega_C \succ \omega_D \succ \omega_L$

(a) Which party will win an election based on the following voting procedures:

- Plurality
- Sequential majority elections with $\omega_L, \omega_D, \omega_C$

(b) Is it possible to fix the election agenda in favour of any outcome?

(c) Assuming that a new fourth party ω_N emerges altering the preferences of the voters to:

- 38% of $|Ag|$ are left-wing voters: $\omega_L \succ \omega_D \succ \omega_N \succ \omega_C$
- 11% of $|Ag|$ are centre-left voters: $\omega_D \succ \omega_L \succ \omega_N \succ \omega_C$
- 39% of $|Ag|$ are right-wing voters: $\omega_C \succ \omega_D \succ \omega_L \succ \omega_N$
- 12% of $|Ag|$ are voters of the new party: $\omega_N \succ \omega_C \succ \omega_D \succ \omega_L$

In favour of which party is it possible to fix the election agenda in sequential majority elections?

(d) Determine the winner of the election using the following voting procedures:

- The Borda count
- The Slater ranking

C13 Consider the following coalitional games:

- (The glove game) Players have left and right hand gloves and they are trying to form pairs. Players 1 and 2 have right hand gloves whereas player 3 has a left hand glove. The agents have the following value function:

$$v(C) = \begin{cases} 1 & \text{if } C \in \{\{1,3\}, \{2,3\}, \{1,2,3\}\} \\ 0 & \text{otherwise} \end{cases}$$

- (The treasure of Sierra Madre game) 3 people find a treasure of many gold pieces in the mountains of Sierra Madre. Each piece can be carried by two people but not by a single person. The valuation function of this game is:

$$v(C) = \lfloor \frac{|C|}{2} \rfloor$$

(a) Compute the Core

(b) Compute the Shapley value for both games.

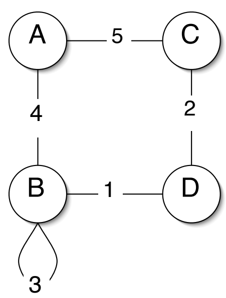
O9 Consider the following weighted voting game: $\langle 10; 6, 4, 2 \rangle$.

(a) Calculate the Shapley-Shubik power index for all players.

(b) How important is the role of player 3 in the game?

(c) Suppose we add one more player to the game: $\langle 10; 6, 4, 2, 8 \rangle$. How does this affect the role of player 3?

O10 The following is an induced subgraph representation of the characteristic function of a cooperative (coalitional) game among four players A, B, C, and D:



(a) Calculate $v(\{B\})$, $v(\{A, B\})$, and $v(\{A, C, D\})$.

(b) Calculate the Shapley value for each agent.

(c) Explain what the Shapley values could be used for and why they provide a strong solution concept.

Week 6 material

C14 Prove the following statement: “Bidding one’s own valuation in a Vickrey auction is the dominant strategy for a rational agent.”
You can assume we are only considering private value auctions among purely self-interested, rational and risk-neutral agents.

C15 Consider a situation in which two agents 1 and 2 bid for items a and b. We assume that each agent is allowed to obtain only one item. The agents have the following valuation functions:

$$v_1(\{a\}) = 12$$
$$v_1(\{b\}) = 3$$
$$v_2(\{a\}) = 6$$
$$v_2(\{b\}) = 1$$

(a) Which allocation will be assigned by the Vickrey-Clarke-Groves mechanism (VCG Mechanism) if both agents are truthful about their valuations?

(b) Calculate the utility each agent will pay to the mechanism.

(c) Can the agents benefit by lying about their true valuation functions?

O11 Discuss which of the English, Vickrey, first-price sealed bid, or Dutch auction protocols guards better against bidder collusion.

O12 Describe the ultimatum game in the context of bargaining. Explain in what sense equilibrium analysis yields counter-intuitive results in this game, and under which circumstances these occur. What changes in the game if we introduce a notion of time, and assume that time affects utility?

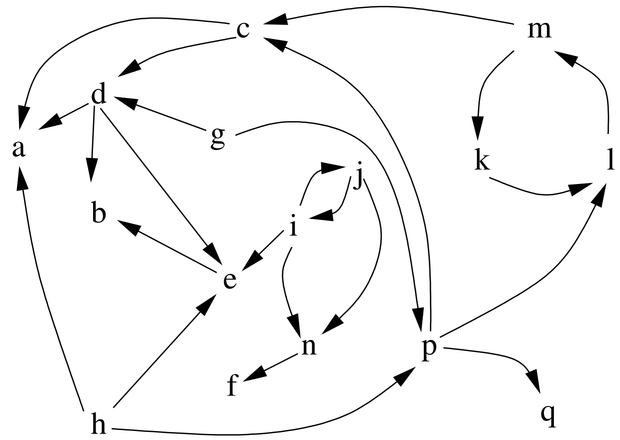
Week 7 material

C16 Consider the following distribution of utilities for two agents 1 and 2 in a task-oriented negotiation domain:

Deal	$cost_1$	$cost_2$
Θ	5	5
d_1	4	1
d_2	0	4
d_3	2	2
d_4	2	3

Trace the way negotiation would proceed using the monotonic concession protocol in this example if agents used the Zeuthen strategy (you may assume that in the first round, agent 2 proposes deal d_1 and agent 1 proposes deal d_2).

C27 Consider the abstract argumentation system depicted in the following graph:



(a) Construct the grounded extension.
(b) Construct the preferred extension(s).
(c) Which arguments can be credulously justified?
(d) Which arguments can be sceptically justified?

O13 We came across the notion of Pareto optimal solutions in three different contexts in the course:

(a) Pareto efficient joint strategies in normal-form games
(b) The Pareto condition that is desirable for voting protocols
(c) Pareto optimal bargaining deals in task-oriented domains

Define each of these concepts using the respective formal definitions of strategies, outcomes, and deals for these three models, giving an example for each case, or a method whose solutions satisfy the criterion.

O14 Consider the following set of logical sentences used for a logic-based argumentation system:

$FeedsPeople(Rice)$	$Sustainable(Biofuel)$
$\forall x\ Sustainable(x) \Rightarrow Useful(x)$	$\forall x\ FeedsPeople(x) \Rightarrow Useful(x)$
$\forall x\ Priority(x) \Rightarrow Useful(x)$	$\forall x\ Useful(x) \Rightarrow Cultivate(x)$
$\forall x\ FeedsPeople(x) \Rightarrow Priority(x)$	$\forall x\ \forall y\ (Cultivate(x) \wedge x \neq y) \Rightarrow \neg Cultivate(y)$

Construct the following arguments if they exist or explain why they don't:

(a) An argument A that supports $Cultivate(Biofuel) \wedge Cultivate(Rice)$,
(b) an argument that rebuts A, and
(c) an argument that undercuts A.

Would you rather accept $Cultivate(Biofuel)$ or $Cultivate(Rice)$? Justify your answer by making reference to concrete formal arguments that can be constructed using the above knowledge base.