Practical Session
Multi-Agent Oriented Programming
The JaCaMo Platform
Web Intelligence Master 2012

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Outline

1. The JaCaMo Multi-Agent Oriented Programming Platform
2. Building House Use Case

Putting the Pieces Together

Agent meta-model

~ The JaCaMo Platform
**Environment meta-model**

- Workspace
- Artifact
- Operation

- Observable Property
- Observable Event

**Organisation meta-model**

- Structural Specification
  - Group
  - Role
- Normative Specification
  - Social Scheme
- Functional Specification
  - Goal
  - Mission

**JaCaMo Meta-Model**
JaCaMo Platform

JaCaMo Wizard

Downloads

- JaCaMo within the eclipse platform
  - Jason ≥ 1.3.7 https://jason.sf.net
  - Jason Eclipse Plugin
    https://docs.google.com/document/pub?id=1URDYMtFP64rHn1b7GcnKyUGbapWcZmeWupwD5p6sM
- Other Relevant URLs and Projects
  - JaCaMo http://jacamo.sourceforge.net
  - Jason http://jason.sourceforge.net
  - CArtAgO http://cartago.sourceforge.net
  - Moise http://moise.sourceforge.net
  - JaCaMo-Arduino (see JaCaMo website)
  - http://jason.sourceforge.net/jBook

Configuring the Infrastructure
Outline

- The JaCaMo Multi-Agent Oriented Programming Platform
  - Global view
  - Setting-up the JaCaMo platform

- Building House Use Case
  - Scenario
  - Multi-Agent Oriented Modelling
    - Contracting Phase
    - Building Phase
  - Multi-Agent Oriented Programming
    - Contracting Phase
    - Building Phase
Giacomo, a CyberWorld addict, wants to build a house.

Two main phases are considered:

- **Contracting specialised companies**
  - Giacomo hires various companies specialised in different aspects of house construction.
  - The companies are independent and want to keep their autonomy of decision.

- **Building of the house**
  - Contracted companies execute the main workflow for building the house.
  - Giacomo supervises the execution of the workflow.

Tasks for which companies should be contracted:
- (a) Site preparation
- (b) Lay floors
- (c) Build walls
- (d) Build roof
- (e) Fit windows
- (f) Fit doors
- (g) Install the plumbing
- (h) Install the electrical system
- (i) Paint the exterior of the house
- (j) Paint the interior of the house

The objective of this practical work is to use the different abstract dimensions participating in the definition of Multi-Agent Oriented Programming to program a Multi-Agent System that could support the execution of this scenario.

Given the constrained framework of a course, this complex application is simplified while keeping the following features:
- Companies and Giacomo delegated part of their decisions to agents: one or several agents for Giacomo, one or several agents for each company.
- Agents attached to Giacomo or Company are autonomous: no central control is possible.
- Open system (companies may leave or enter the system at any moment) and dynamic environment.
Modelling common to both phases

- House Owner Agent (Giacomo’s assistant):
  - provides the requirements for the house, with budget limitations
  - helps Giacomo in the different decisions: contracting companies, managing and supervising the workflow execution
- Company Agent:
  - offer the house building services, skills and resources of the company
  - if hired, execute the house building tasks

Modelling Contracting Phase

- Interaction Modelling: since the different companies aim at keeping their autonomy, choice of a negotiation protocol in order to build contracts between Giacomo and the different companies for each of the tasks
- Organisation Modelling: flat organisation is defined with no particular role
- Environment Modelling: no particular environment concerns are considered in this phase

Modelling Building Phase

- Interaction Modelling: At the end of the contracting phase, Giacomo contact the hired companies to enter into the execution phase and enact the negotiated workflow
- Organisation Modelling: a virtual organisation is created to assist with coordination and cooperation in the execution of the global workflow
- Environment Modelling: Graphical Interface to show the global state of the building

Interactions

- Use of Electronic Auctions to hire the required companies
  - One auction for each task
  - Each auction is started with:
    - the task description
    - the maximum value the owner can pay for it
  - By the end of an auction, the company to be hired for that task is determined
JaCaMo

Organisation

- Moise functional specification is used to define the workflow
- Moise structural specification is used to define the role and group structures
- Moise normative specification is used to distribute the tasks of the workflow to the roles

Functional Specification

- The functional specification simply defines a social scheme for the global workflow
- $a; b; c; (d|e|f); (g|h|i); j$
- One mission for each task except for the painting of the exterior and of the interior of the house that are grouped into the same mission
- A task for the management of the execution of the workflow is also added

Example: Organisation Functional Specification

- Roles: house_owner, building_company (abstract role), site_prep_contractor, bricklayer, roofer, window_fitter, door_fitter, plumber, electrician, painter
- Inheritance Hierarchy: building_company abstract role, specialised into: site_prep_contractor, bricklayer, roofer, window_fitter, door_fitter, plumber, electrician, painter
- Group: roles are used in a house_group group
**Structural Specification**

In group `house_group`,

- cardinalities are:
  - (1,1) for `house_owner`, `site_prep_contractor`, `roofer`, `window_fitter`, `door_fitter`, `plumber`, `electrician`, `painter`
  - (1,2) for `bricklayer`;
- the same agent can play more subroles → the role `building_company` is compatible with `building_company`
- role `house_owner` has authority over the `building_company` role
- a communication link connects the role `build_company` to `house_owner`

**Example: Organisation Structural Specification**

<table>
<thead>
<tr>
<th>norm</th>
<th>modality</th>
<th>role</th>
<th>mission / goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>n1</td>
<td>O</td>
<td><code>house_owner</code></td>
<td>house built</td>
</tr>
<tr>
<td>n2</td>
<td>O</td>
<td><code>site_prep_contractor</code></td>
<td>site prepared</td>
</tr>
<tr>
<td>n3</td>
<td>O</td>
<td><code>bricklayer</code></td>
<td>floors laid, walls built</td>
</tr>
<tr>
<td>n4</td>
<td>O</td>
<td><code>roofer</code></td>
<td>roof built</td>
</tr>
<tr>
<td>n5</td>
<td>O</td>
<td><code>window_fitter</code></td>
<td>windows fitted</td>
</tr>
<tr>
<td>n6</td>
<td>O</td>
<td><code>door_fitter</code></td>
<td>doors fitted</td>
</tr>
<tr>
<td>n7</td>
<td>O</td>
<td><code>plumber</code></td>
<td>plumbing installed</td>
</tr>
<tr>
<td>n8</td>
<td>O</td>
<td><code>electrician</code></td>
<td>electrical system installed</td>
</tr>
<tr>
<td>n9</td>
<td>O</td>
<td><code>painter</code></td>
<td>interior painted, exterior paint</td>
</tr>
</tbody>
</table>

**Example: Organisation Normative Specification**

```
norm    modality role               mission / goals
n1       O        house_owner   house built
n2       O        site_prep_contractor site prepared
n3       O        bricklayer    floors laid, walls built
n4       O        roofer       roof built
n5       O        window_fitter windows fitted
n6       O        door_fitter  doors fitted
n7       O        plumber      plumbing installed
n8       O        electrician  electrical system installed
n9       O        painter      interior painted, exterior paint
```

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Main files

- house-map-tut.mas2j: project
- src/asl: agent code
- src/java: environment code
- src/house-os.xml: organisation code
- Initial project
  http://sourceforge.net/projects/jacamo/files

Programming Agents

- The House owner agent is programmed in *Jason*
- The Company Agents are programmed in *Jason* (or 2APL, Jadex, ...)
  → Heterogeneous Agent System

Programming Interaction in the Environment

- Encapsulation of the auction mechanism in an auction artifact
- Giacomo creates instances of such artifacts for creating/managing the various auctions; one such auction is used for hiring companies for each of the house building tasks
- Companies can perceive those artifacts and bid according to their competence and following their own strategies
- After some time Giacomo decides to finish the auction, observing the current best bid shown on the artifact

Auction Artifact

- observable properties:
  - task description
  - maximum payment value
  - current best bid (lower service price)
  - current winning agent ID
- operation:
  - bid(p): places a new bid for doing the service for price p (used by company agents to bid in a given auction)
programming interaction in the agent side

- giacomo agent:
  - plans to launch all auctions by creating the corresponding auction artifacts
  - after some time looks at the best bid in each auction artifact and awards a contract for the winning company

- company agents:
  - plans to look for the auction artifacts of their interest
  - plans defining their own bidding strategy

/* artifact that implements the auction. */
public class AuctionArt extends Artifact {

  @OPERATION public void init(String taskIds, int maxValue) {
    // observable properties
    defineObsProperty("task", taskIds);
    defineObsProperty("maxValue", maxValue);
    defineObsProperty("currentBid", maxValue);
    defineObsProperty("currentWinner", "no_winner");
  }

  @OPERATION public void bid(double bidValue) {
    ObsProperty opCurrentValue = getObsProperty("currentBid");
    ObsProperty opCurrentWinner = getObsProperty("currentWinner");
    if (bidValue < opCurrentValue.intValue()) { // the bid is better
      opCurrentValue.updateValue(bidValue);
      opCurrentWinner.updateValue(getOpUserName());
    }
  }
}

/* initial goal */
@have a house.

/* plans */
+@have a house <- @contract; // hire the companies that will build the house
  execute. // simulates the execution of the construction

/* plans for contracting */
+@contract
  <- @create_auction_artifacts;
  @wait_for_bids.
JaCaMo
Use Case
Scenario
Modelling
Programming

src/asl/companyA.asl

```plaintext
// This company bids for Plumbing only
// Strategy: fixed price

{ include("common.asl") }
my_price(300), // initial belief
!discover_art("auction_for_Plumbing").
+currentBid?{artifact_id(Acts)} // there is a new value for current bid
  | not _sent_bidding(Acts) #  // I am not the current winner
  | my_price() > ?<  // I can offer a better bid
  | <> print("my bid in auction artifact ", Acts, ": ", Price");
  | bid( #). // place my bid offering a cheaper service

/* plans for execution phase */
{ include("org_code.asl") }

// plan to execute organisational goals (not implemented)
| +plumbing_installed // the organisational goal (created from an obligation)
<- installPlumbing, // simulates the action (in GUI artifact)
```

Homework

1. Change the auction artifact so that it shows and manages the bidding deadline and has a new operation for starting the auction; the clearAuction operation is no longer needed
2. Create a new company for one of the tasks and give it any bidding strategy you like
3. Choose a new auction mechanism and implement a new auction artifact that implements that mechanism; you should not change the agents for this exercise
4. Now choose another mechanism that will require different strategies in the agents and implement them

Exercises

- Change the code of the auction artifact to:
  1. create a new observable property that shows the state of the auction (open or closed)
  2. add a new operation clearAuction (after clearAuction, the state of the auction becomes closed and attempts to use the bid operation will fail)
- Change the house owner program so that the agent uses the new clearAuction operation

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Programming Agents for the Building Phase

- Giacomo Agent is enriched with:
  - Plan to send messages to the hired companies to enter into the execution phase, after all auctions are over.
  - Plan to build the virtual organisation based on the result of the contracting phase: allocating the different roles to the contracted company agents

- Company Agent:
  - Plans to enter the organisation, adopt the role corresponding to their contract and to catch the different events generated by the Organisation
  - Plans to execute autonomously the various actions related to the goals related to the missions they are committed to in the organisation scheme
  - NB: agents are benevolent with respect to the organisation, i.e. they don’t violate the norms

Programming Organisation

- Moise functional specification is used to define the workflow
- Moise structural specification is used to define the role and group structures
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Programming Environment

- Artifacts that model the state of the environment (e.g., model the state of the construction of a wall)

Exercises

Do the following changes in the organisation specification:

- tasks site_preparation and lay_floors can be done in parallel
- all tasks have to be done in sequence
Develop an agent that tries to adopt roles related to tasks he is not supposed to (malevolent agent!) (e.g. Giacomo trying to play some company role)

Develop an agent that does not fulfil the tasks

Change the Giacomo agent so that it reacts to the norm violation. Giacomo should create a new auction for that task and forbid the violating company from taking part in the new auction

Change the system to build two houses in parallel

Change the Giacomo agent so that it reads the Moise specification and creates the necessary auction artifacts based on the specified tasks

Change Giacomo so that it is able to monitor the building of the house and check whether the tasks are being done appropriately