Distributed Artificial Intelligence and Intelligent Agents

Exercise : Introduction to JADE

Aims of this exercise

- To get knowledge about Java-based programming environments for MAS
- To learn the JADE environment as a possible tool for implementing the course project.
- To create awareness of the types of systems that are available and generate ideas about how such systems can be created

JADE Platform

- JADE (Java Agent Development Environment)
  - http://jade.tilab.com/
- Version 4.5 (current version)
- Simple registration needed on website

JADE

JADE is a middleware that facilitates the development of multi-agent systems. It includes

- A **runtime environment** where JADE agents can "live" and that must be active on a given host before one or more agents can be executed on that host.
- A **library** of classes that programmers have to/can use (directly or by specializing them) to develop their agents.
- A suite of **graphical tools** that allows administrating and monitoring the activity of running agents.

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Author: Giovanni Caire (TILAB, formerly CSELT)

JADE overview

- ***Container*** - Each running instance of the JADE runtime environment (it can contain several agents).
- ***Platform*** - The set of active containers.
- A single special ***Main container*** must always be active in a platform and all other containers register with it as soon as they start.

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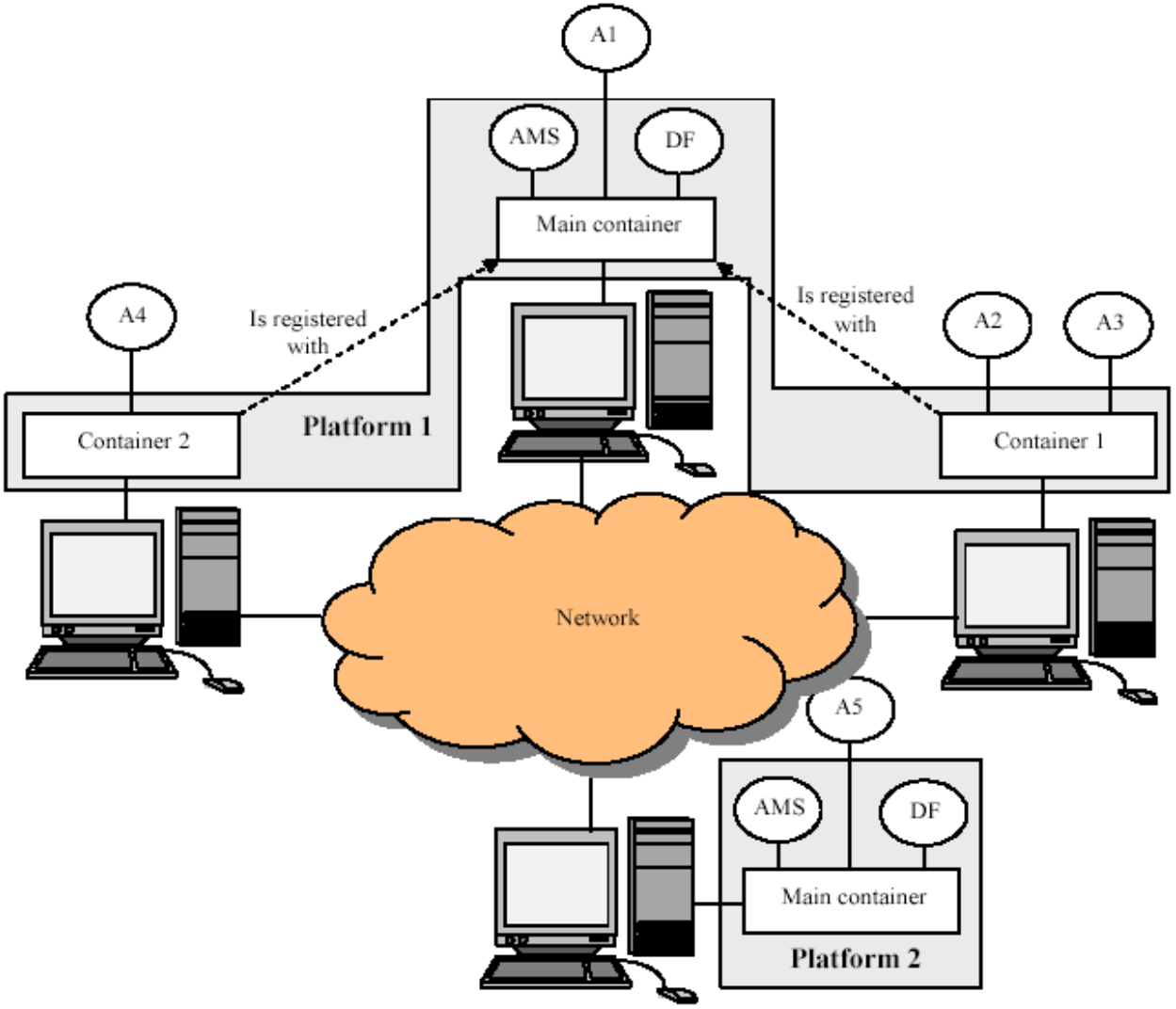
JADE overview

- Agent Management System (AMS) - white page service, the list of agents in the system
- Directory Facilitator (DF) - yellow page service, the list of service available from agents
- You can start, suspend and kill agents

JADE overview



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Creating agents (BookTrading example)

```
package examples.bookTrading

import jade.core.Agent;
public class BookBuyerAgent  extends Agent {
  protected void setup() {
     //  Printouta welcome message
          System.out.println(
               "Hallo! Buyeragent"
               + getAID().getName()
               +" is  ready.");
     }
}
```

- The setup() method is intended to include agent initializations.
- The actual job an agent has to do is typically carried out within "behaviours"

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Agent identifiers

- Each agent is identified by an "agent identifier" represented as an instance of the jade.core.AID class.
- The **`getAID()`** method of the Agent class allows retrieving the agent identifier. An AID object includes a globally unique name plus a number of addresses.
- The name in JADE has the form *<nickname>@<platform-name>* so that an agent called *misha* living on a platform called *IMIT* will have

  misha@IMIT as globally unique name.

AID can be obtained knowing agent's nickname:

```
String nickname = "Peter";
AID id =  newAID(nickname, AID.ISLOCALNAME);
```

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Running Agents

- Compilation

```
javac -classpath <JADE-classes>
    BookBuyerAgent.java
```

- Running

```
java -classpath <JADE-classes>;.
    jade.Boot buyer:BookBuyerAgent
```

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Passing arguments to an agent

```
java jade.Boot
     buyer:BookBuyerAgent(The-Lord-of-
     the-rings)
```

Book Trading Example

- Each buyer agent receives the title of the book to buy (the "target book") as a command line argument
- It periodically requests all known seller agents to provide an offer.
- As soon as an offer is received the buyer agent accepts it and issues a purchase order.
- If more than one seller agent provides an offer the buyer, the gent accepts the best one (lowest price).
- Having bought the target book the buyer agent terminates.
- Each seller agent has a minimal GUI by means of which the user can insert new titles (and the associated price) in the local catalogue of books for sale.
- Seller agents continuously wait for requests from buyer agents. When asked to provide an offer for a book they check if the requested book is in their catalogue and in this case reply with the price. Otherwise they refuse. When they receive a purchase order they serve it and remove the requested book from their catalogue.

Passing arguments to an agent

```
import jade.core.Agent;
import jade.core.AID;
public class BookBuyerAgent extends Agent {
    // The title of the book to buy
private String targetBookTitle;
    // The list of known seller agents
private AID[] sellerAgents = {new AID("seller1", AID.ISLOCALNAME), new
    AID("seller2", AID.ISLOCALNAME)};
    // Put agent initializations here
protected void setup() {
    // Printout a welcome message
          System.out.println("Hallo! Buyer-agent "+getAID().getName()+"  is ready");
     // Get the title of the book tobuy as a start-up argument
     Object[] args = getArguments();
     if (args != null && args.length > 0)
          {  targetBookTitle = (String)
          args[0];
          System.out.println("Trying to buy "+targetBookTitle);
    }
    else {
          // Make the agent terminate immediately
          System.out.println("No book title specified");
          doDelete();
    }
}
    // Put agent clean-up operations here
protected void takeDown() {
                                        "+getAID().getName()+" terminating.");
}
```

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Behaviours

- The actual job an agent has to do is typically carried out within "behaviours".
- A behaviour represents a task that an agent can carry out and is implemented as an object of a class that extends **`jade.core.behaviours.Behaviour`**.
- Behaviour is added to agent by means of the **`addBehaviour()`** method of the Agent class.
- Behaviours can be added at any time
- Each class extending Behaviour must implement the **`action()`** method, that actually defines the operations to be performed when the behaviour is in execution and the **`done()`** method (returns a boolean value), that specifies whether or not a behaviour has completed and have to be removed from the pool of behaviours an agent is carrying out.
- An agent can execute several behaviours concurrently.
- When a behaviour is scheduled for execution its **`action()`** method is called and runs until it returns.

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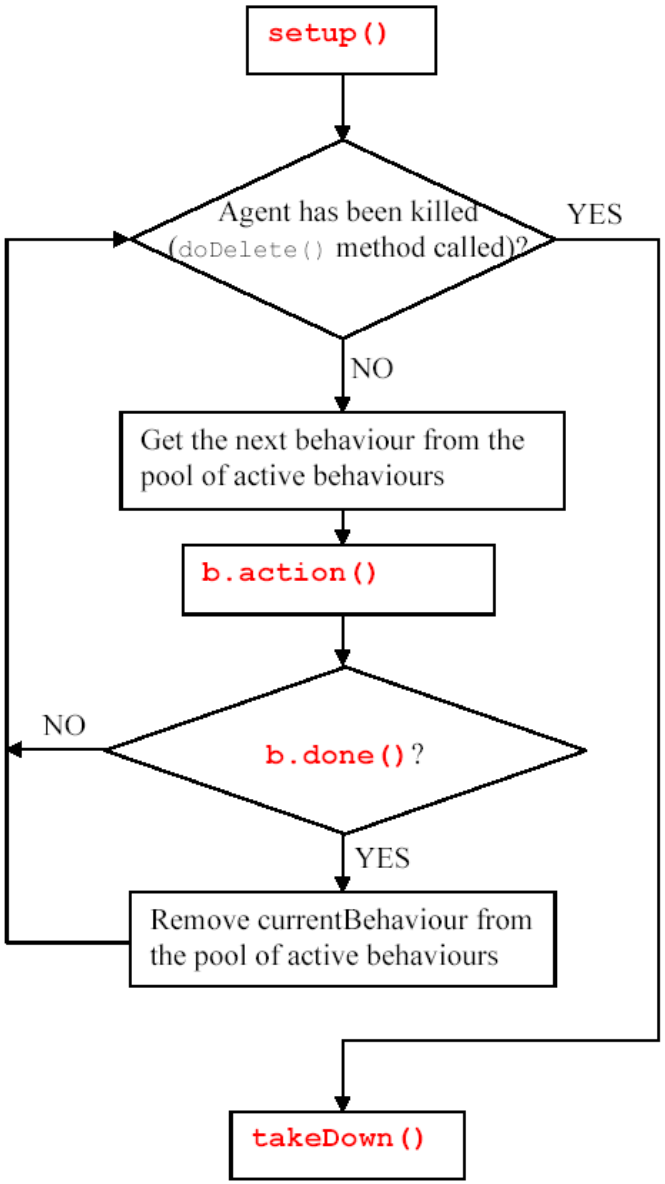
Agents execution



- Initializations
- Addition of initial behaviours

Highlighted in red the methods that programmers have to implement

- Agent "life" (execution of behaviours)

- Clean-up operations

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Behaviour examples

This behaviour never stops

```
public class OverbearingBehaviour extends
                    Behaviour {
  public void action()
     {  while (true) {
           // do something
     }
  }
  public boolean done()
     {  return true;
  }
}
```

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Available Behaviours

- **`jade.core.behaviours.Behaviour`** - base class for all behaviours; needed only in the case of special synchronisation needs
- **`jade.core.behaviours.CompositeBehaviour`** - holds a number of children behaviours; this class must be extended to provide the actual scheduling policy to apply when running children behaviours
- **`jade.core.behaviours.CyclicBehaviour`** - atomic behaviour that is executed forever

Available Behaviours

- **`jade.core.behaviours.FSMBehaviour`** - CompositeBehaviour that executes its children behaviours according to a finite state machine (FSM) defined by the user

- **`jade.core.behaviours.OneShotBehaviour`** - atomic behaviour that executes just once

- **`jade.core.behaviours.ParallelBehaviour`** - CompositeBehaviour with concurrent children scheduling; it terminates when a particular condition on its sub-behaviours is met i.e. when all children are done, N children are done or any child is done

Available Behaviours

- **`jade.core.behaviours.ReceiverBehaviour`** - behaviour for receiving an ACL message; this behaviour terminates when an ACL message is received

- **`jade.core.behaviours.SenderBehaviour`** - behaviour for sending an ACL message; this behaviour sends a given ACL message and terminates

- **`jade.core.behaviours.SequentialBehaviour`** - CompositeBehaviour with sequential children scheduling; executes its children behaviours in sequential order, and terminates when its last child has ended

Available Behaviours

- **`jade.core.behaviours.SimpleBehaviour`** - atomic behaviour, which models behaviours that are made by a single, monolithic task and cannot be interrupted

- **`jade.core.behaviours.TickerBehaviour`** - behaviour that periodically executes a user-defined piece of code

- **`jade.core.behaviours.WakerBehaviour`** - **`OneShotBehaviour`** that is executed only once just after a given timeout is elapsed

Creating Behaviours

"One-shot" behaviour

```
public class MyOneShotBehaviour  extends
       OneShotBehaviour{
   public void action() {
        // perform operation X
   }
}
```

"Cyclic"

```
public class MyCyclicBehaviour  extends CyclicBehaviour{
   public void action() {
        // perform operation Y
   }
}
```

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Creating Behaviours

- Generic behaviour

```
public class MyThreeStepBehaviour extends Behaviour {
   private int step = 0;
   public void action() {
        switch (step) {
        case 0:
                // perform operation X
                step++;
                break;
        case 1:
                // perform operation Y
                step++;
                break;
        case 2:
                // perform operation Z
                step++;
                break;
        }
   }
   public boolean done()
        {  return step ==
        3;
   }
}
```

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Adding behaviours

```
public class MyAgent extends Agent
   {  protected void setup() {
        System.out.println("Adding waker behaviour");
        addBehaviour(new WakerBehaviour(this, 10000) {
              protected void handleElapsedTimeout() {
                    // perform operation X
              }
        } );
   }
}
```

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Adding behaviours

```
public class MyAgent extends Agent
  {  protected void setup()
     {  addBehaviour(
           new TickerBehaviour(this, 10000)
           {  protected void onTick() {
                // perform operation Y
           }
     } );
  }
}
```

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Book-buyer agent behaviours

```
protected void setup() {
   // Printout a welcome message
   System.out.println("Hallo! Buyer-agent
        "+getAID().getName()+" is ready.");
   // Get the title of the book to buy as a start-up argument
   Object[] args = getArguments();
   if (args != null && args.length > 0)
        {  targetBookTitle = (String)
        args[0];
        System.out.println("Trying to buy "+targetBookTitle);
   // Add a TickerBehaviour that schedules a request to seller
   // agents every minute
   addBehaviour(new TickerBehaviour(this, 60000)
        {  protected void onTick()
                {  myAgent.addBehaviour(new
                RequestPerformer());
        }
   } );
}
else {
   // Make the agent terminate
   System.out.println("No target book title specified");
   doDelete();
   }
}
```

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Book-seller agent behaviours

```
import jade.core.Agent;
import jade.core.behaviours.*;
import java.util.*;
public class BookSellerAgent extends Agent {
   // The catalogue of books for sale (maps the title of  a book
   to //its price)
   private Hashtable catalogue;
   // The GUI by means of which the user  can add books in the
   //catalogue
   private BookSellerGui myGui;
   // Put agent initializations here
   protected void setup()
        // Create {  the
        catalogue catalogue
        // Create = new Hashtable();
        myGui = new BookSellerGui(this);
        myGui.show();
        // Add the behaviour serving requests for offer from
   buyer        //agents
        addBehaviour(new OfferRequestsServer());
        // Add the behaviour serving purchase orders from buyer
        //agents
        addBehaviour(new PurchaseOrdersServer());
   }
```

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Book-seller agent behaviours

```
   // Put agent clean-up operations here
   protected void takeDown() {
        // Close the GUI
        myGui.dispose();
        // Printout a dismissal message
        System.out.println("Seller-agent
                "+getAID().getName()+" terminating.");
   }

/**
This is invoked by the GUI when the user adds a new book  for sale
*/
   public void updateCatalogue(final String  title, final  int price){
        addBehaviour(new OneShotBehaviour()  {
                public void action() {
                        catalogue.put(title, new Integer(price));
                }
        } );
   }
}
```

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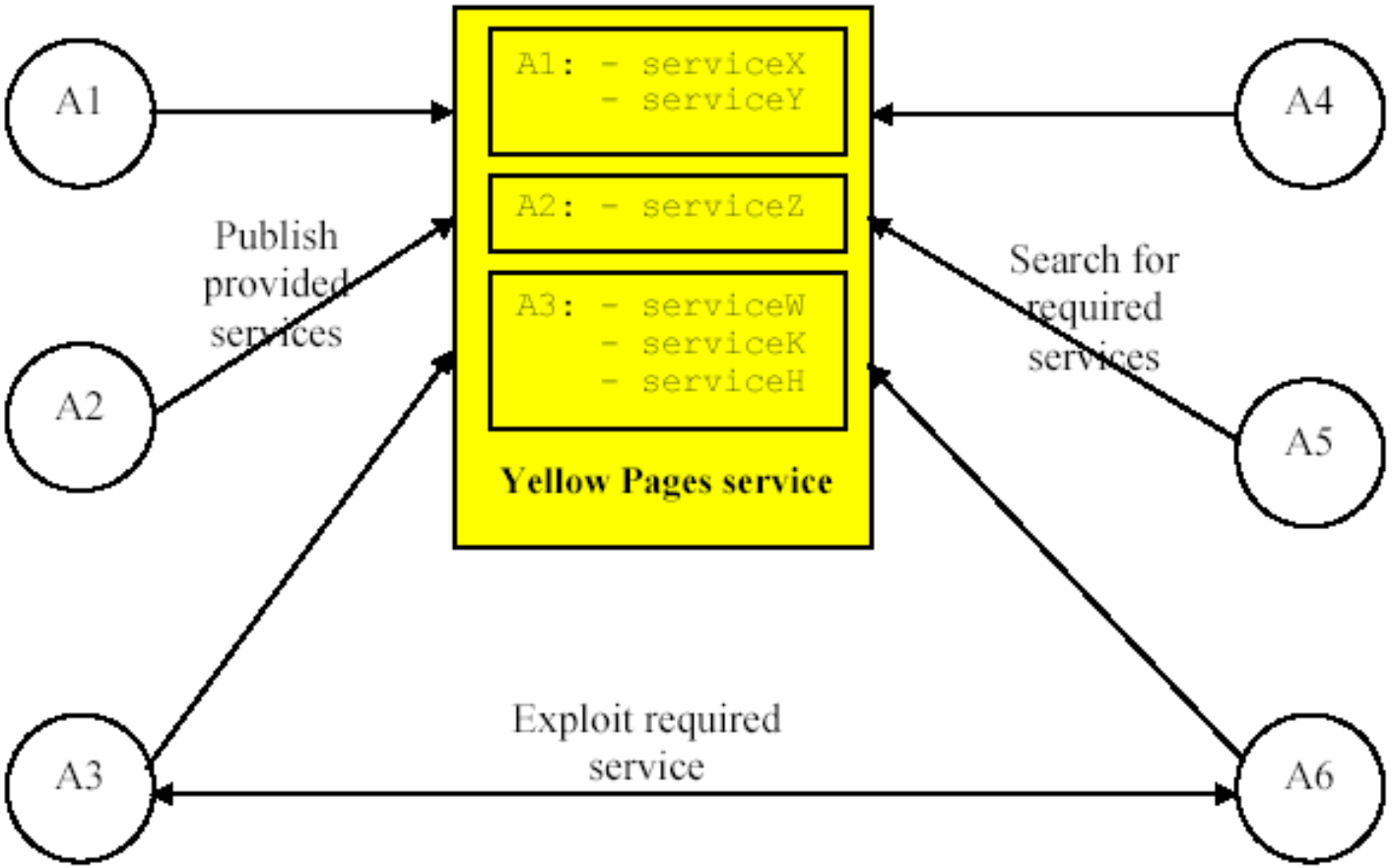
THE DF SERVICE CLASS



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DFAgentDescription

```
DFAgentDescription
  Name: AID // Required for registration
  Protocols: set of Strings
  Ontologies: set of Strings
  Languages: set of Strings
  Services: set of {
      { Name: String // Required for each
                     //service specified
      Type: String   // Required ...
      Owner: String Protocols: set of Strings
      Ontologies: set of Strings
      Languages: set of Strings
      Properties: set of
            { Name: String
               bValue: String
            }
      }
```

Interacting with the DF (Publishing services)

```
protected void setup() {
   ...
   // Register the book-selling service in the yellow pages
   DFAgentDescription dfd = new DFAgentDescription();
   dfd.setName(getAID());
   ServiceDescription sd = new ServiceDescription();
   sd.setType("book-selling");
   sd.setName("JADE-book-trading");
   dfd.addServices(sd);
   try {
       DFService.register(this, dfd);
   }
   catch (FIPAException fe)
       {  fe.printStackTrace
       ();
   }
   ...
}
```

This simple example and we do not specify any language, ontology or service-specific property.

Interacting with the DF (Publishing services)

```
void register( ServiceDescription sd)
{ DFAgentDescription dfd = new
     DFAgentDescription();
  dfd.setName(getAID());
  dfd.addServices(sd);
  try
                                    dfd );
  }  {  DFService.register(th
  catcihs,(FIPAException fe)
  {  fe.printStackTrace(); }
}
```

Usage:

```
ServiceDescription sd = new
     ServiceDescription();
sd.setType( "buyer" );
sd.setName( getLocalName() );
register( sd );
```

Interacting with the DF (de-registrating)

```
protected void takeDown() {
  // Deregister from the yellow pages
  try {
     DFService.deregister(this);
  }
  catch (FIPAException fe)
     {  fe.printStackTrace()
     ;
  }
  // Close theGUI
     myGui.dispose();
  //  Printouta dismissal message
     System.out.println("Seller-agent
     "+getAID().getName()+"terminating.");
}
```