DIS, La Sapienza - PhD Course

Autonomous Agents and Multiagent Systems

Lecture 2: Overview of Techniques and Tools for MAS Development

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Types of Work on **Multiagent Systems**

- Agent Communication Languages: speech acts languages, content languages, ontologies
- Protocol Design & Negotiation: mechanisms for reaching agreements between competitive agents, often through auctions; based on game and economic theory; analysis of protocol properties

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Types of Work on **Multiagent Systems**

- Task Allocation & Coordination: mechanisms for allocating tasks & sharing results, multiagent planning, ensuring that team members stay coordinated
- Multiagent Platforms/Infrastructures: languages and tools for programming MAS, providing basic services such as networking, yellow pages, etc.; e.g. SRI's Open Agent Architecture (OAA), Telecom Italia's Java Agent Development Environment (JADE), which is FIPA compliant
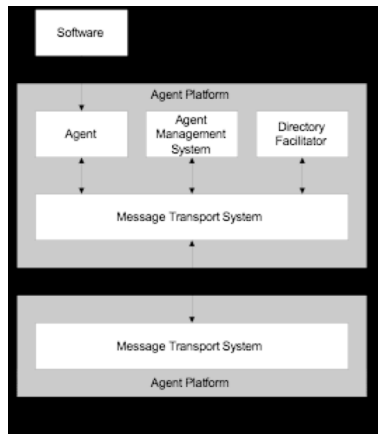
FIPA Standards

- Foundations for Intelligent Physical Agents (FIPA) defined standards for MAS since 96, now an IEEE committee
- Several categories of standards: abstract architecture, agent management, agent communication, message transport, and applications

FIPA Agent Management Reference Model

•Agent Management System controls access & maintains directory of agents

•Directory Facilitator provide yellow pages service

•Message Transport System supports message transmission within & outside platform

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Speech Act Theory

- Human (agent) communication is a form of action
- Speech act theory tries to model this
- Searle's classes of speech acts:
    - Representatives, e.g. inform
    - Directives, e.g. request
    - Commissives, e.g. promise
    - Expressives, e.g. thanking
    - Declaratives, e.g. declare married

Speech Act Theory

- Some speech acts are denoted by a performative verb, e.g. inform, request, etc.
- Some speech acts are indirect, e.g. "Can you close the window?"
  "I am cold"
- Many formalizations, e.g. [Cohen & Levesque 90b]

DARPA Knowledge Sharing Effort (KSE)

- Developed models of communication between knowledge-based systems
- Separate content and "envelope" of message
- Envelope understandable even if content is not
- Proposed Knowledge Interchange Format (KIF) as content language, essentially FOL with predefined types & definitions in a Lisp syntax
- Knowledge Query and Manipulation Language (KQML) for envelope layer

KQML

- E.g. KQML message
  ```
  (ask-one
      :content (PRICE IBM ?price)
      :receiver stock-server
      :language LPROLOG
      :ontology NYSE-TICKS)
  ```
- Message labeled with performative/speech act
- Other parameters `:sender, :receiver, :content, :ontology, :reply-with,` etc.

KQML

- Large set of performatives, e.g.
  ```
  advertize, broker-one, stream-all, subscribe
  ```
- But no commissives
- Semantics specified late

FIPA Agent Communication Language (ACL)

- Message structure similar to KQML
- Smaller set of performatives
- Semantics defined in Semantic Language (SL), a version of Cohen & Levesque's logic developed by Sadek
- E.g. inform, request, query-if, call-for-proposal
- See FIPA Communicative Act Library Specification http://www.fipa.org/specs/fipa00037/SC00037J.pdf
- SL and some subsets are also content languages

Interaction Protocols

- Specify "conversation types", what kind of message is allowed under what conditions
- See e.g. FIPA request, query, & contract net protocol specs at http://www.fipa.org/repository/standardspecs.html

Contract Net Protocol [Smith 77]

- Auction-like mechanism for task sharing/delegation
- Involves initiator/manager & participants/ possible bidders
- Stages:
    1. Task announcement/call for bids
    2. Bidding by participants
    3. Awarding of contract by initiator
    4. (Follow up)

An MAS Platform: OAA

- Open Agent Architecture (OAA) is a platform for building MAS developed at SRI
- Evolved from blackboard systems from distributed AI, where entities (often rule-based) exchange information by putting it on the blackboard
- OAA provides facilitator agent(s) that act as a matchmaker
- Agents tell facilitator about their capabilities, i.e. declare "solvables"

OAA

- Queries/requests (OAAsolve) are routed by the facilitator to an agent that can fulfill them
- Agents communicate in Interagent Communication Language (ICL)
- ICL is somewhat speech acts-based, with Prolog-style syntax
- OAA provides libraries for implementing agents in Java, various Prologs, etc. that support communication with facilitator

OAA

- Good for rapid prototyping & integrating components implemented in different programming languages
- Facilitator can be a bottleneck
- Suitable for MAS with limited number of agents & message traffic

Another MAS Platform: JADE

- Java Agent Development Environment (JADE) platform, developed at Telecom Italia Labs
- FIPA-compliant
- Java-based (library)
- Peer-to-peer communication model

JADE

- Tries to keep communication & concurrency overhead low
- Agents running on given host implemented in single thread in single Java VM & message passed as objects using Java events (no serialization or conversion to String)
- Can have multiple agents containers running on several hosts, with message passing done using Java RMI (with serialization)
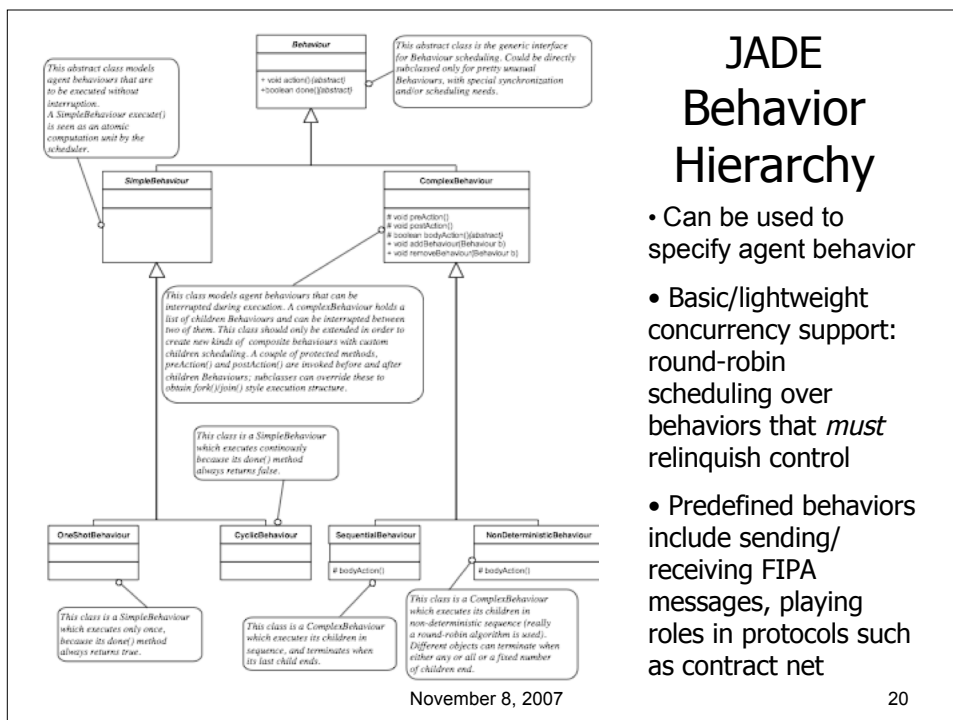
JADE

- Supports communication with other FIPA-compliant platforms using CORBA IIOP (with String conversion)
- Agents don't need to know how communication is implemented
- Elements of FIPA agent management reference model provided (AMS, DF, etc.)

JADE Behavior Hierarchy

- Can be used to specify agent behavior

- Basic/lightweight concurrency support: round-robin scheduling over behaviors that *must* relinquish control

- Predefined behaviors include sending/receiving FIPA messages, playing roles in protocols such as contract net

JADE

- Provides some MAS monitoring facilities with GUI
- Supports use of Java Expert System Shell (JESS) for implementing rule-based agents
- Jadex is a BDI agent programming framework developed on top of JADE by University of Hamburg
- Semantics AddOn supports semantic processing of msgs, inference, behavior spec