Programming Languages for Multiagent Systems

Multiagent Systems LS

Sistemi Multiagente LS

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Ingegneria Due

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1. Spaces for Programming Languages in Software Engineering
   - Paradigm Shifts
   - Examples
2. Spaces for Programming Languages in Multiagent Systems
   - Programming Agents
   - Programming MAS
3. Spaces for Programming Languages in the A&A Meta-model
   - Generality
   - Environment, Coordination, Organisation & Security
4. Remarkable Cases of (Programming) Languages for Multiagent Systems

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Paradigm Shifts in Software Engineering

New classes of programming languages

- New classes of programming languages come from paradigm shifts in Software Engineering[a]
  - new meta-models / new ontologies for artificial systems build up new spaces
  - new spaces have to be "filled" by some suitably-shaped new (class of) programming languages, incorporating a suitable and coherent set of new abstractions
- The typical procedure
  - first, existing languages are "stretched" far beyond their own limits, and become cluttered with incoherent abstractions and mechanisms
  - then, academical languages covering only some of the issues are proposed
  - finally, new well-founded languages are defined, which cover new spaces adequately and coherently

[a] SE here is taken in its broadest acceptation as the science of building software system, rather than the strange "theoretically practical" discipline you find at ICSE... Otherwise, one may easily see the thing the other way round

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The Problem of PL & SE Today

Things are running too fast

- New classes of programming languages emerge too fast from the needs of real-world software engineering
- However, technologies (like programming language frameworks) require a reasonable amount of time (and resources, in general) to be suitably developed and stabilised, before they are ready for SE practise

→ Most of the time, SE practitioners have to work with languages (and frameworks) they know well, but which do not support (or, incoherently / insufficiently support) required abstractions & mechanisms

→ This makes methodologies more and more important with respect to technologies, since they can help covering the "abstraction gap" in technologies

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An Example: CORBA & Distributed Objects

OOP technologies moving too slow

- As soon as OOP moved out of academia to enter SE practises, new needs had already emerged
- Distribution of software applications required new solutions, and created new spaces for programming languages
- Distributed objects were the first answer, and distributed infrastructures like CORBA were developed
- On the one hand, new (classes of) languages like IDL were introduced
- On the other hand, the development of a stable & reliable technology was so slow, that the first "usable" CORBA implementation (3.0) came too late, and never established itself as the standard reference technology

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Another Example: Java & Web Technologies

- What is the standard framework for distributed systems today?
  - Java, for distributed objects
  - The Web, for most distributed applications
- None of them, however, was born for this
  - Java was born as a programming language
    - today Java is typically conceived as a platform, or a distributed framework
  - The Web was born as a mere concept, implemented via HTML pages, server & browsers
    - today the Web is a sort of cluster of related technologies in disordered growth
- Both of them suffer from a *lack of conceptual coherence*
  - in Java, syntax and basic language mechanisms are the only glue
  - in Web technologies, the client / server pattern is the only unifying model
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The Agent Abstraction

MAS programming languages have *agent* as a fundamental abstraction

- An agent programming language should support one (or more) agent definition(s)
  - so, straightforwardly supporting mobility in case of mobile agents, intelligence somehow in case of intelligent agents, ..., by means of well-defined language constructs
- Required agent features play a fundamental role in defining language constructs

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Agent Architectures

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  - agent architectures will follow soon
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Agent Observable Behaviour

MAS programming languages support agent *model of action*

- Agents act
  - through either communication or pragmatical actions
- Altogether, these two sorts of action define the admissible space for agent's observable behaviour
  - a *communication language* defines how agents speak to each other
  - a "language of pragmatical actions" should define how an agent can act over its environment
- A full-fledged agent language should account for both languages
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Agent Behaviour

Agent computation vs. agent interaction / coordination

- Agents have both an internal behaviour and an observable, external behaviour
  - this reproduce the "computation vs. interaction / coordination" dichotomy of standard programming languages
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  - the observable behaviour of an agent as a computational component is *driven* / *governed* by the agent itself
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Intra-agent languages, *Inter-agent* languages

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Example: Agent Communication Languages (ACL)

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Agents Without Agent Languages

What if we do not have an agent language available?

- For either theoretical or practical reasons, it may happen
  - we may need an essential Prolog feature, or be required to use Java
- What we do need to do: *(1) define*
  - adopt an agent definition, along with the agent's required / desired features
  - choose agent architecture accordingly, and according to the MAS needs
  - define a model and the languages for agent actions, both communicative and pragmatical
- What we do need to do: *(2) map*
  - map agent features, architecture, and action model / languages upon the existing abstractions, mechanisms & constructs of the language chosen
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Outline

1. Spaces for Programming Languages in Software Engineering
   - Paradigm Shifts
   - Examples
2. Spaces for Programming Languages in Multiagent Systems
   - Programming Agents
   - Programming MAS
3. Spaces for Programming Languages in the A&A Meta-model
   - Generality
   - Environment, Coordination, Organisation & Security
4. Remarkable Cases of (Programming) Languages for Multiagent Systems

Programming the Interaction Space

The space of MAS interaction

- Languages to interact roughly define the space of (admissible) MAS interaction
- Languages to interact should not be merely seen from the viewpoint of the individual agent (*subjective viewpoint*)
- The overall view on the space of (admissible) MAS interaction is the MAS engineer's viewpoint (*objective viewpoint*)
  - *subjective* vs. *objective* viewpoint over interaction [Schumacher, 2001, Omicini and Ossowski, 2003]

Enabling / governing / constraining the space of MAS interaction

- A number of inter-disciplinary fields of study insist on the space of (system) interaction
  - coordination
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Coordination in short

- Many different definitions around
  - we will talk about this later on in this course—we need to simplify, here
- In short, coordination is managing / governing interaction in any possible way, from any viewpoint
- Coordination has a typical “dynamic” acceptation
  - that is, enabling / governing interaction at execution time
- Coordination in MAS is even a more chaotic field
  - again, a useful definition to harness the many different acceptations in the field is subjective vs. objective coordination—the agent's vs. the engineer's viewpoint over coordination [Schumacher, 2001, Omicini and Ossowski, 2003]

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- It mainly concerns the structure of a system
  - it is mostly design-driven
- It affects and determines admissible / required interactions permissions / commitments / policies / violations / fines / rewards / ...
- Organisation is still enabling & ruling the space of MAS interaction
  - but with a more "static", structural flavour
  - such that most people mix-up "static" and "organisation" improperly
- Organisation in MAS is first of all, a model of responsibilities and power
  - typically based on the notion of *role*
  - requiring a model of communicative & pragmatical actions
  - e.g. RBAC-MAS [Omicini et al., 2005]

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Governing interaction in MAS

- Coordination, organisation & security all mean managing (MAS) interaction
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MAS Interaction Space in the A&A Meta-model

MAS interaction & A&A

- Agents *speak* with agents
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Artifacts as MAS computational entities

- Artifacts are computational entities
  - with a *computational* (internal) *behaviour*
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Intra-agent languages for artifacts

- Artifact computational behaviour is reactive
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Programming Languages for Artifacts: A&A Features

A&A cognitional artifact features in languages

- An artifact language may deal with artifact's usage interface
- An artifact language may deal with artifact's operating instructions
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Other artifact features in languages

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Programming Languages for Artifacts: The Environment

Artifacts & MAS Environment

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Layering Agent Workspace

A conceptual experiment

A layered taxonomy
[Molesini et al., 2006]

- Individual artifacts
  - handling a single agent's interaction
- Social artifacts
  - handling interaction among a number of agents / artifacts
- Environment artifacts
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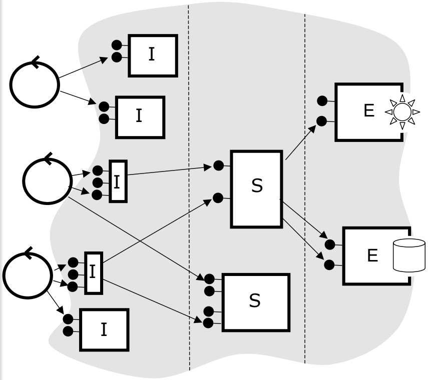

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Individual artifacts

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  - on the basis of organisational / security concerns
- If an individual artifact is the only way by which an agent can interact within a MAS
  - **organisation** there, role, permissions, obligations, policies, etc., should be encapsulated
  - **security** working as a filter for any perception / action / communication between the agent, MAS and the environment
  - **autonomy** it could work as the harmoniser between the clashing needs of agent autonomy and MAS control
  - **boundaries** it could be used as a criterion for determining whether an agent belongs to a MAS
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Languages for individual artifacts

- Declarative languages (KR-style) for our "quasi static" perception of organisation
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- Typically operational, event-driven languages for our "dynamic" perception of coordination
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Artifacts for MAS Environment

Environment artifacts

- Environment artifacts are the most natural place where to rule interaction between a MAS and its environment
  - on the basis of artifact reactivity to change
- Spatio-temporal fabric as a source of events
  - time time events for temporal concerns
  - space spatial events for topological concerns
- Resources as sources of events and targets of actions
  - like a database, or a temperature sensor
- Our (limited) example: Situated/Timed Tuple Centres [Omicini et al., 2007, Casadei and Omicini, 2009]
  - coordination abstractions reactive to passing of time and external events
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Agent Communication Languages (ACL)

Speech acts

- Inspired by the work on human communication
- Communication based on direct exchange of messages between agents
  - specifying agent communicative actions
- Speaking agent acts to change the world around
  - in particular, to change the belief of another agent
- Every message has three fundamental parts

  performative the pragmatics of the communicative action

  content the syntax of the communicative action

  ontology the semantics of the communicative action
- Our examples, working as standard protocols for information exchange between agents

  KQML Knowledge Query Manipulation Language
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Programming languages for cognitive agents

- Mentalistic agents
  - either BDI or other cognitive architectures
- Facilities and structures to represent internal knowledge, goals, ...
- Architecture to implement practical reasoning
- Our examples

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Jason Java-based interpreter for an extended version of AgentSpeak(L) for programming BDI agents
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Languages to program social / environment artifacts

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- ReSpecT tuple centres as social artifacts
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- ReSpecT tuple centres as social artifacts
  - ReSpecT as the event-driven, logic-based language to program tuple centres behaviour
  - Timed ReSpecT as an event-driven language to react to environment change

Artifact Programming Languages: Coordination

Languages to program social / environment artifacts

- Our example: ReSpecT
  - Programming language for cognitive agents
    `http://respect.alice.unibo.it/`
    [Omicini, 2007, Omicini and Denti, 2001]
- Tuple centres as coordinative artifacts
  - programmable tuple spaces
  - encapsulating coordination policies
- Logic tuple centres as awareness artifacts
- ReSpecT tuple centres as social artifacts
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Artifact Programming Languages: Organisation / Security

Languages to program individual artifacts

- Our example: Agent Coordination Context (ACC)
  - individual artifact
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Non-Agent Programming Languages

Building the agent abstraction layer

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  - **Java** programming simple agents in Java: examples in TuCSoN

Agents using artifacts

- Our examples
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3. Spaces for Programming Languages in the A&A Meta-model
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4. Remarkable Cases of (Programming) Languages for Multiagent Systems

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