Programming Languages for Multiagent Systems

Multiagent Systems LS
Sistemi Multiagente LS

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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
Outline

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4. **Remarkable Cases of (Programming) Languages for Multiagent Systems**
**Paradigm Shifts in Software Engineering**

**New classes of programming languages**

- New classes of programming languages come from paradigm shifts in Software Engineering:
  - 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

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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 ultra-fast 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

MAS programming languages support agent architectures

- Agents have (essential) features, but they are built around an agent architecture, which defines both its internal structure, and its functioning.
- An agent programming language should support one (or more) agent architecture(s):
  - e.g., the BDI (Belief, Desire, Intention) architecture [Rao and Georgeff, 1991]
  - agent architectures will follow soon
- Agent architectures influence possible agent features
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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
  - so little work on languages of pragmatical actions, however
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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

- so, what is new here?

- Agent autonomy is new
  - the observable behaviour of an agent as a computational component is driven / governed by the agent itself
  - e.g., intelligent agents do practical reasoning—reasoning about actions—so that computation “computes” over the interaction space—in short, agent coordination
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Space for PL in MAS  Programming Agents

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**Intra-agent languages, Inter-agent languages**

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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 pragmatically

- 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

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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 & pragmaticallyal actions
  - e.g. RBAC-MAS [Omicini et al., 2005]
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- Coordination, organisation & security all mean managing (MAS) interaction.
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Artifacts for coordination, organisation & security

- Governing the interaction space essentially means coordination, organisation & security
  - More or less the same holds for building agent workspace
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Programming Languages for Artifacts: The 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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- Individual artifacts are the most natural place where to rule individual agent interaction within a MAS 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

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Languages for individual artifacts

- Declarative languages (KR-style) for our “quasi static” perception of organisation
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- Coordination policies could be distributed upon social artifacts, and there encapsulated
  - inspectability: there, coordination policies could be explicitly represented and made available for inspection
  - controllability: functioning of coordination engine could be controllable by engineers / agents
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  - interaction happens, the artifact has just to capture interaction and to react appropriately
- Our example: ReSpecT
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  - ongoing work on multiset rewriting semantics (with Maude)

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  - time events for temporal concerns
  - space events for topological concerns

- Resources as sources of events and targets of actions
  - like a database, or a temperature sensor

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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

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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
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Artifact Programming Languages: Coordination

Languages to program social / environment artifacts

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Articfact Programming Languages: Organisation / Security

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  - associated to each individual agent in a MAS
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Non-Agent Programming Languages

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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

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Conclusions

Programming Languages for Multiagent Systems

Multiagent Systems LS
Sistemi Multiagente LS

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