The Many Agents Around

Distributed Systems

Sistemi Distribuiti

Andrea Omicini

andrea.omicini@unibo.it

Dipartimento di Informatica – Scienza e Ingegneria (DISI)

Alma Mater Studiorum – Università di Bologna a Cesena

Academic Year 2015/2016

Convergence Towards The Agent

Many areas contribute their own notion of agent

- Artificial Intelligence (AI)
- Distributed Artificial Intelligence (DAI)
- Parallel & Distributed Systems (P&D)
- Mobile Computing
- Programming Languages and Paradigms (PL)
- Software Engineering (SE)
- Robotics

On the Notion of Intelligence in AI

Reproducing intelligence

- AI is first of all concerned with reproducing *intelligent processes* and *behaviours*, where
  - intelligent processes roughly denote *internal* intelligence—like understanding, reasoning, representing knowledge, ...
  - intelligent behaviours roughly represent *external*, observable intelligence—like sensing, acting, communicating, ...

Symbolic intelligence

- Classic AI promoted the so-called *symbolic* acceptation of (artificial) intelligence
  - based on *mental representation* of the external environment
  - where the environment is typically oversimplified
  - and the agent is the only source of disruption

On the Notion of Agent in AI

Encapsulating intelligence

- Agents in AI have from the very beginning worked as the units encapsulating *intelligence*
  - *individual* intelligence
  - within the symbolic interpretation of intelligence

Cognitive agents

- AI agents are essentially cognitive agents
  - they are *first* cognitive entities
  - *then* active entities
  - in spite of their very name, coming from Latin *agens* [*agere*]—the one who acts

AI & Agents—A Note

Reversing perspective [OP06]

- Today, results from AI and MAS research are no longer so easily distinguishable
- Agents and MAS have become the introductory metaphors to most of the AI results
  - as exemplified by one of the most commonly used AI textbooks [RN02]
- Classic AI results on planning, practical reasoning, knowledge representation, machine learning, and the like, have become the most obvious and fruitful starting points for MAS research and technologies
- It is quite rare nowadays that new findings or lines of research in AI might ignore the agent abstractions at all
- Altogether, rather than a mere subfield of AI, agents and MAS could be seen as promoting a new paradigm, providing a new and original perspective about computational intelligence and intelligent systems

On the Notion of Agent in DAI [Woo02]

Overcoming the individual dimension

- no more a single unit encapsulating individual intelligence
- and acting *alone* within an oversimplified environment

Social acceptation of agency

- agents are individuals within a society of agents
  - agents are components of a *multiagent system* (MAS)
- agents are distributed within a *distributed environment*

Agent Features in DAI [OJ96]

A DAI agent...

- ...has an explicit representation of the world
- ...is situated within its environment
- ...solves a problem that requires intelligence
- ...deliberates / plans its course of actions
- ...is flexible
- ...is adaptable
- ...learns

A DAI Agent Represents the World: What?

What should be represented?

- What is relevant? What is not relevant?
  - More precisely, which knowledge about the environment is relevant for an agent to effectively plan and act?
  - So, which portion of the environment should the agent explicitly represent somehow in order to have the chance to behave intelligently?

Representation is partial

- Necessarily, an agent has a *partial* representation of the world
- Its representation includes in general both the current *state* of the environment, and the *laws* regulating its dynamics

A DAI Agent Represents the World: How?

The issue of Knowledge Representation (KR)

- How should an agent represent knowledge about the world?
- Representation is not neutral with respect to the agent's model and behaviour
  - and to the engineer's possibilities as well
- Choosing the right KR language / formalism
  - according to the agent's (conceptual & computational) model
  - multisets of tuples, logic theories, description logics, . . . ?

A DAI Agent Represents the World: Consistency I

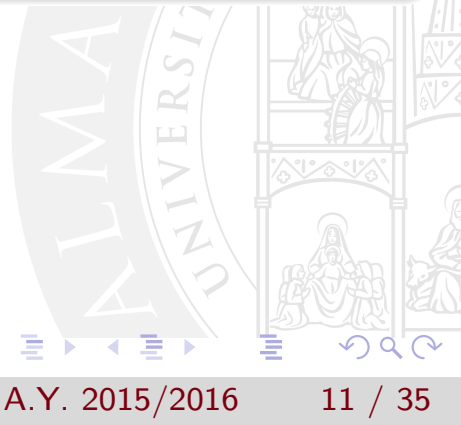
Perception vs. representation

- Environment changes, either by agent actions, or by its own dynamics
- Even supposing that an agent has the potential to observe all the relevant changes in the environment, it can not spend all of its activity monitoring the environment and updating its internal representation of the world
- So, in general, how could consistency of internal representation be maintained? And to what extent?
  - in other terms, how and to what extent can an agent be ensured that its knowledge about the environment is at any time consistent with its actual state

A DAI Agent Represents the World: Consistency II

Reactivity vs. proactivity

- An agent should be *reactive*, sensing environment changes and behaving accordingly
- An agent should be *proactive*, deliberating upon its own course of actions based on its mental representation of the world
- So, more generally, how should the duality between reactivity and proactivity be ruled / balanced?



A DAI Agent Solves Problems I

An agent has inferential capabilities

- New data representing a new solution to a given problem
- New knowledge inferred from old data
- New methods to solve a given problem
- New laws describing a portion of the world

An agent can change the world

- An agent is equipped with actuators that provide it with the ability to affect its environment
- The nature of actuators depends on the nature of the environment in which the agent is immersed / situated
- In any case, agent's ability to change the world is indeed limited

A DAI Agent Deliberates & Plans I

An agent has a goal to pursue

- A *goal*, typically, as a state of the world to be reached—something to achieve
- A *task*, sometimes, as an activity to be brought to an end—something to do

A DAI Agent Deliberates & Plans II

An agent understands its own capabilities

- Its capabilities in terms of actions, pre-conditions on actions, effects of actions
- "Understands" roughly means that its admissible actions and related notions are somehow represented inside an agent, and there suitably interpreted and handled by the agent
- Perception should in some way interleave with action either to check action pre-conditions, or to verify action effects

A DAI Agent Deliberates & Plans III

An agent is able to build a plan of its actions

- It builds possible plans of action according to its goal/task, and to its knowledge of the environment
- It deliberates on the actual course of action to follow, then acts consequently

A DAI Agent is Flexible & Adaptable

Define *flexible*. Define *adaptable*.

- What do these words *exactly* mean?
- Adaptable / flexible with respect to what?
- Can an agent change its goal dynamically?
- Or, can it solve different problems in different contexts, or in dynamics contexts?
- Can an agent change its strategy dynamically?
- These properties are both important and potentially misleading, since they are apparently intuitive, and everybody thinks he/she understands them exactly

A DAI Agent Learns I

What is (*not*) learning?

- Learning is not merely agent's change of state
- Learning is not merely dynamic perception—even though this change the agent's state and knowledge

What could an agent learn?

- New knowledge
- New laws of the world
- New inferential rules?
  - new ways to learn?

A DAI Agent Learns II

A number of areas insisting on this topic

Machine Learning, Abductive / Inductive Reasoning, Data Mining, Neural Networks, ...

DAI Agents: Summing Up

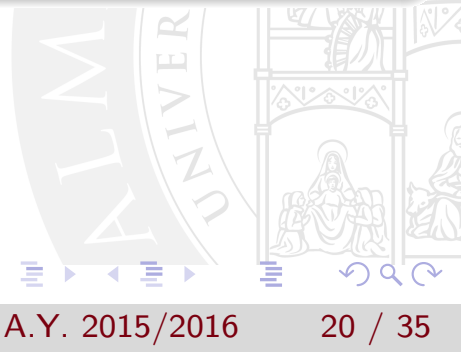
In the overall, a DAI agent has a number of important features

- It has a (partial) representation of the world (state & laws)
- It has a limited but dynamic perception of the world
- It has inferential capabilities
- It has a limited but well-known ability to change the world
- It has a goal to pursue (or, a task to do)
- It is able to plan its course of actions, and to deliberate on what to do actually
- Once understood what this means, it might also be flexible and adaptable
- It learns, regardless of how this term is understood

A PL Agent is Autonomous in Control

Complexity is in the control flow

- The need is to abstract away from control
- An agent encapsulates control flow
- An agent is an independent *locus* of control
- An agent is never invoked—it merely follows / drives its own control flow
- An agent is *autonomous* in control
  - it is never invoked—it cannot be invoked



A PL Agent is neither a Program, nor an Object

An agent is not merely a program

- A program represents the *only* flow of control
- An agent represents a single flow of control within a multiplicity

An agent is not merely a "grown-up" object

- An object is invoked, and simply responds
- An agent is never invoked, and can deliberate whether to respond or not to any stimulus

A P&D Agent is mobile [FPV98]

An agent is not bound to the Virtual Machine where it is born

- Reversing the perspective
  - it is not that agents are mobile
  - it is that objects are not
- *Mobility* is then another dimension of computing, just uncovered by agents

A new dimension requires new abstractions

- New models, technologies, methodologies
- To be used for reliability, limitations in bandwidth, fault-tolerance, ...

A Robotic Agent is Physical & Situated

A robot is a physical agent

- It has both a computational and a physical nature
  - complexity of physical world enters the agent boundaries, and cannot be confined within the environment

A robot is intrinsically situated

- Its intelligent behaviour cannot be considered as such separately from the environment where the robot lives and acts
- Some intelligent behaviour can be achieved even without any symbolic representation of the world
  - non-symbolic approach to intelligence, or *situated action* approach [Bro91]
- *Reactive architectures* come from here

A SE Agent is an Abstraction

An agent is an abstraction for engineering systems

- It encapsulate complexity in terms of
  - information / knowledge
  - control
  - goal / task
  - intelligence
  - mobility
- Agent-Oriented Software Engineering (AOSE)
  - engineering computational systems using agents
  - agent-based methodologies & tools

A MAS Agent is a Melting Pot I

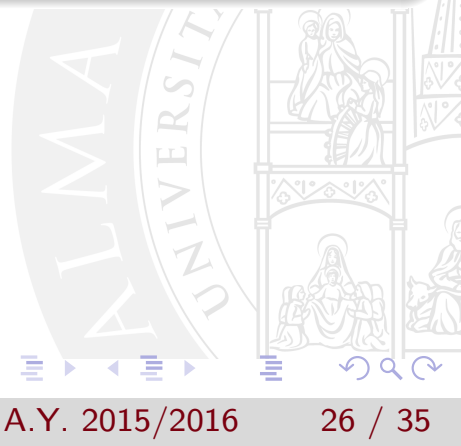
Putting everything together

- The area of Multiagent Systems (MAS) draws from the results of the many different areas contributing a coherent agent notion
- The MAS area is today an independent research field & scientific community
- As obvious, MAS emphasise the *multiplicity* of the agents composing a system

A MAS Agent is a Melting Pot II

Summing up

- A MAS agent is an autonomous entity pursuing its goal / task by interacting with other agents as well as with its surrounding environment
- Its main features are
  - autonomy / proactivity
  - interactivity / reactivity / situatedness



A MAS Agent is Autonomous

A MAS agent is goal / task-oriented

- it encapsulates control
- control is finalised to task / goal achievement

A MAS agent pursues its goal / task...

- ...proactively
- ...not in response to an external stimulus

So, what is new here?

- agents are goal / task oriented...
- ...but also MAS as wholes are
- *individual* vs. *global* goal / task
  - how to make them coexist fruitfully, without clashes?

A MAS Agent is Interactive I

Limited perception, limited capabilities

- it depends on other agents and external resources for the achievement of its goal / task
- it needs to interact with other agents and with the environment [Agr95]
  - communication actions & pragmatical actions

A MAS agent lives not in isolation

- it lives within an agent *society*
- it lives immersed within an agent *environment*

A MAS Agent is Interactive II

Key-abstractions for MAS

- agents
- society
- environment

Summing Up I

The notion of agent is multi-faceted

- Many reliable scientific sources
- Many more or less convergent / divergent definitions
- A synthesis is currently ongoing in the MAS community

Finally, defining the agent notion

- It is now possible...
- ...but it is also insufficient, now
- to fully define MAS

Summing Up II

Meta-model is incomplete

- What about agent society?
- What about agent environment?

References I

Philip E. Agre.
Computational research on interaction and agency.
Artificial Intelligence, 72(1-2):1–52, January 1995.
Special volume on computational research on interaction and agency, part 1.

Rodney A. Brooks.
Intelligence without representation.
Artificial Intelligence, 47:139–159, 1991.

Alfonso Fuggetta, Gian Pietro Picco, and Giovanni Vigna.
Understanding code mobility.
IEEE Transactions on Software Engineering, 24(5):342–361, May 1998.

References II


Gregory M.P. O'Hare and Nicholas R. Jennings, editors.
Foundations of Distributed Artificial Intelligence.
Sixth-Generation Computer Technology. John Wiley & Sons Ltd., hardcover edition, April 1996.


Andrea Omicini and Agostino Poggi.
Multiagent systems.
Intelligenza Artificiale, III(1-2):76–83, March-June 2006.
Special Issue: The First 50 Years of Artificial Intelligence.


Stuart J. Russell and Peter Norvig.
Artificial Intelligence: A Modern Approach.
Prentice Hall / Pearson Education International, Englewood Cliffs, NJ, USA, 2nd edition, 20 February 2002.

References III

Michael J. Wooldridge.
An Introduction to MultiAgent Systems.
John Wiley & Sons Ltd., Chichester, UK, March 2002.

The Many Agents Around

Distributed Systems

Sistemi Distribuiti

Andrea Omicini

andrea.omicini@unibo.it

Dipartimento di Informatica – Scienza e Ingegneria (DISI)

Alma Mater Studiorum – Università di Bologna a Cesena

Academic Year 2015/2016