Engineering Multi-Agent Systems

What does it mean to make progress in our community? Defining a Research Agenda.

TU Delft
Koen V. Hindriks
May 7, 2013
2005 Roadmap for Agent Based Computing

• Agent Technology: Computing as Interaction
• Authors: Luck, McBurney, Shehory, Willmott

• Some of the goals:
  • identify areas of critical importance in agent technology, and focus work in agent systems
  • improve quality, profile, and industrial relevance of research in agent-based computing
Are drivers driving us?

Drivers are different communities?

What is driving us?
<table>
<thead>
<tr>
<th>Topic</th>
<th>Short Term</th>
<th>Medium Term</th>
<th>Long Term</th>
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</thead>
<tbody>
<tr>
<td>Industrial Strength software</td>
<td>Peer to peer</td>
<td>Generic designs for coordination</td>
<td>Best practice in agent systems design</td>
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<td>Better development tools</td>
<td>Libraries for agent-oriented development</td>
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<td>Agent UML</td>
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<td>Service oriented computing</td>
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<td>FIPA ACL</td>
<td>Flexible business/trading languages</td>
<td>Tools for evolutions of communications languages and protocols</td>
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<td>Peer to peer</td>
<td>Libraries of interaction protocols</td>
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<td>Service oriented computing</td>
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<td>Semantic description</td>
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<td>Web mining</td>
<td>Semantic interaction</td>
<td>Shared, improved ontologies</td>
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<td>Data integration and Semantic Web</td>
<td>Agent-enabled semantic web (services)</td>
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<td>Electronic institutions</td>
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<td>Metadata</td>
<td>Dynamic norms, roles, laws, organisations</td>
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<td>Organisational views of agent systems</td>
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<td>Adaptation</td>
<td>Enhanced understanding of agent society dynamics</td>
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<td>Personalisation</td>
<td>Theory and practice of argumentation strategies</td>
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<td>Hybrid technologies</td>
<td>Norms and social structure</td>
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<td>Theory and practice of negotiation strategies</td>
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<td>Learning Technologies</td>
<td>Evolving Agents</td>
<td>Run-time reconfiguration and re-design</td>
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<td>Reasoning in Open Environments</td>
<td>Self organisation</td>
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<td>Trust and Reputation</td>
<td>Distributed learning</td>
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<td>AgentLink Roadmap 2005</td>
<td>Security and verifiability for agents</td>
<td>Trust techniques for coping with malicious agents</td>
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<td>Reliability testing for agents</td>
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<td>Self-enforcing protocols</td>
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<td>Norms and social structures</td>
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<td>Reputation mechanisms</td>
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<td>Formal methods for open agent systems</td>
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<td>Electronic contracts</td>
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As a community we have aimed at combining SE and AI

- Engineering Agents (SE)
  - Verification
  - Tooling
  - APLs Scalable, Modular
  - Methodologies
  - Common Sense
  - Reasoning (KR)
  - Learning
  - Planning
  - Multi-Agent Coordination

- Cognitive Agents (AI)

Research → Applied

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Where are we now?

Some achievements

**AAMAS community**
- Yoav Shoham's paper Agent-oriented programming, AI, 1993 won the 2011 IFAAMAS Award for Influential Papers (2505 citations)
- An empirical study has shown that agent technology repeatedly produces substantial savings in time and effort when developing logistics software, with the average programming productivity increase being over 350%.
  (Benfield et al, AAMAS 2006)
- ...

**Industry**
- Massive Software specializes in autonomous agent technology for animating realistic crowd behaviors.
- In Sim City, for the first time, every pedestrian, every car and every building in the game is an agent, reporting in to the main simulation.
  (The Guardian, 2012)
- JACK used for impact analysis of an air traffic management system.
  (AOS website, 2011)
- ...

May 30, 2014

TUDelft
We have achieved a lot!

*Agent technologies, methodologies, and tools (ATMTs)*

<table>
<thead>
<tr>
<th>Methodologies</th>
<th>Agent Technologies</th>
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<tr>
<td>GAIA</td>
<td>2APL</td>
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<td>OperA</td>
<td>AgentFactory</td>
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<td>O-MASE</td>
<td>Brahms</td>
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<td>Prometheus</td>
<td>CLAIM</td>
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<td>Tropos</td>
<td>GOAL</td>
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<td>Golog</td>
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<td>INGENIAS</td>
<td>Jack</td>
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<td>Jadex</td>
<td>Jason</td>
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<td>JIAC</td>
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<td>MOISE</td>
<td>SimpA</td>
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Some motivation for new Roadmap

• MAS are applied to: gaming, simulation, supply chain management, manufacturing control, business process management, …

• Academic efforts to produce ATMTs for developing multi-agent systems offer principled and systematic approaches and solutions.

• Use of “our” ATMTs is only limited in industry.

• Q: Why not? Hard to apply academic ATMTs?

• Q: Are applications of MAS in industry ad hoc?
Some motivation for new Roadmap

• Given plethora of platforms, how to choose any one of these for the job at hand?

• What are the benefits of a particular choice? What are the strengths and weaknesses of ATMTs?

• How to apply a platform? Do methodologies support the tools and technologies and vice versa?

• A need for standards that support the application of agent technology?

• Are we making progress...?
What does it mean to make progress?

Planning
• RQ: how to automatically construct a plan that achieves a given goal state?
• Precise, conceptual model of state-transition systems.

Engineering MAS
• RQ: What ATMTs make developing MAS easier?
• Conceptual model of autonomous, cognitive agents.

Progress appears to be not as clear for Engineering MAS as it is for Planning.
2012 Dagstuhl Seminar: Engineering Multi-Agent Systems

**Goal:** New Roadmap for Engineering MAS

**Organizers:** Dix, Hindriks, Logan, Wobcke.

**Participants:** 37 from 15 countries.

**Results:**
- AOSE, ProMAS, DALT merged into EMAS
- Report Engineering Multi-Agent Systems

Also see: [http://www.dagstuhl.de/en/program/calendar/semhp/?semnr=12342](http://www.dagstuhl.de/en/program/calendar/semhp/?semnr=12342)
Dagstuhl Seminar Motivation

We expect that the **interaction** in a Dagstuhl seminar is ideal for establishing **common ground** for defining standards, identifying best practices, and designing a **future roadmap** to apply agent technology to large scale or realistic scenarios needed in **industry**.

- **important to establish best practices and evaluate lessons learned from applying agent technology!**
Challenge Area 1: BDI + Agents or Rich Cognitive Agents

Goal: Integrate capabilities (e.g., emotions) systematically into agent architectures.

E.g., challenge is to systematically integrate and design:

- Agents that can learn.
- Agents that can reason with uncertainty.
- Agents that are able to explain their own behavior.
Challenge Area 2: Coordination and Organization of MAS

Goal:
Develop frameworks for coordination/organization of MAS.

- Surprising that classical problems in concurrent systems, e.g., deadlock & starvation, are not studied in community.
- Which concepts and techniques are required to engineer coordination? Integration into organizational models?
- Link with COIN: COIN more concerned with abstractions and much less with implementations?
Challenge Area 3: Tooling and Benchmarks

Goal:
Standards for tooling & benchmarks for agent technology.

• Metrics and benchmarks needed to get grip on, e.g., performance, scalability, believability, flexibility, …
• Tooling is key to the uptake of any technology! Reuse, do not reinvent! Agent-specific tools?
• (Initial) focus on validation and tools for debugging.
• Connect & integrate work from AOP and AOSE!
Challenge Area 4: Agent technology and legacy systems

Goal:
Techniques for integrating agent technology and legacy.

• Agents need to interact with non-agent components without the use of agent communication protocols.
• How to facilitate customization of agent technology to different application scenarios as needed?
• Enable selection of agent platform features needed for a given application to simplify development.
Challenge Area 5: Component-based agent design

Goal:
Identify & develop **component-based** agent architecture.

- Idea is that engineering MAS is facilitated by a set of components that can be easily exchanged and reused.
- Industry developers may be interested in using some but not all components of existing agent architectures.
- Developing such components may give rise to some degree of standardization (reference model).
Issues we need/should want to address as a community, more or less related to various of the challenge areas.

KEY ISSUES
To BDI or not to BDI...


Two major distinctive benefits of agent technology:

- **autonomous decision making**
- **explicit problem decomposition and coordination mechanisms**.

**Key issue**: how can we quantify and demonstrate these benefits? identify application areas where agent technology provides a critical advantage?
Deployment of MAS

Main problems facing deployment of (large-scale) multi-agent systems fall under three related areas:

- integration,
- validation, and
- software engineering

*Key issue:* How can we identify what is specific to agent technology (tooling, methodology, engineering)? Focus on re-use & integration of existing mainstream techniques.
Agent Technology for Developers

Agent technology should benefit the developer!

• Need to supply platforms, methodologies, tooling that facilitates and links to experience of software developers

• Need to study use of our technology in practice to gain insight into issues faced by developers.

• Design of controlled experiments on agent technology.

Key issue: Which empirical approaches can help us identify the needs of and issues faced by agent developers? What support is missing from perspective of agent developer?
Papers

- Need for increased appreciation of and papers on the challenges involved in engineering large-scale MAS.
- Need reports on technological barriers to the deployment of MAS and lessons learned from applications.
- Need for generally software engineering type of papers that use existing agent technologies.

*Key issue:* As a community we need to agree & maintain standards to ensure work in this area is of high quality.
Concluding

Challenge Areas
• BDI + Agents
• Coordination & Organization
• Tooling & Benchmarks
• Agent technology & legacy
• Component-based agents

Key issues
• How can we quantify benefits of agent technology?
• How identify what is specific to agent technology? Re-use!
• Identify needs of and issues faced by agent developers.
• Need to agree on and maintain standards to ensure work is of high quality.