
AGENTS : A QUICK STATE OF THE ART

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1. Introduction

Agents and *multi-agent systems (MAS)* have become one of the most active and lively research areas in computer science worldwide. As a research field it covers a broad spectrum of aspects, from pure technical (hardware-oriented) ones (e.g., low level communication infrastructures) to even social ones (like trust, deception, fraud). MAS research is nurtured by and overlaps with many other research areas. As a consequence many events related to computer science and software engineering cover in a way or another also agent-related topic.

This document focuses on the progress of agent technology, emergent technologies demand and recent developments in agent oriented research. We will point out several areas such e-commerce, e-business, personalization, recommender systems, privacy, virtual organizations and trust.

2. Definition of *Agents*

Times have changed, emergent technologies such as the internet demand personal, continuously running autonomous systems (O'Reilly 2005). So the new generation of systems must be able to behave in an autonomous, flexible manner in unpredictable, dynamic, typically social domains. It is precisely their autonomy that defines agents. Agent is a tool to achieve autonomy to interact in a real world (Wooldridge 1999, Jennings 1998, Hess 2000) "*An agent is a computer system that is capable of flexible autonomous action in dynamic, open, unpredictable and typically multi-agent domains*".

The most recent definition of agent is: *they are a design metaphor (Luck 2005)*.

Agents must decide by themselves whether to execute their methods according to their goals (agents must be pro-active), preferences, and beliefs. Also, agents must be flexible. When designing agent systems, it is impossible to foresee all the potential situations an agent may encounter and specify agent behaviour optimally in advance. Agents therefore have to learn from and adapt to their environment. This task is even more complex when nature is not the only source of uncertainty, and the agent is situated in an environment that contains other agents with potentially different capabilities, goals, and beliefs. (Weiss 1997). Not surprisingly, learning has recently received increasing attention in connection with agents and multi-agent systems (Weiss 1997, Ontañón 2001, Vidal 2002). An agent must also show a social attitude. In an environment populated by heterogeneous entities, agents must have the ability to recognise their opponents, and form groups when it is profitable to do so. Developing agent teams has been a topic of intensive research in the agent community (Dong 2007, Kephart 2003, Jennings 1998). Agents can also assist users teaching or training, making recommendations and helping different users collaborate

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(Zanker 2007, Xu 2005, Ricci 2006, Delfin 2006, Aha 2005, Adomavicius 2005, Aciar 2007 b). In these situations, agents are regarded as the technology in which the IT and telecommunications sectors should converge. They have a role to play at the client-side of such systems, providing customers with personalised, proactive interfaces to new services and products (Ricci 2006, Aciar 2007 b). In e-commerce scenario they have a role to play as middleware, putting users in contact with the goods and services that best suit their needs. And they have a role to play as servers, cooperating and negotiating on behalf of organisations and other end users [(Muntaner 2007, Muntaner 2006, Acebo 2007, Aciar 2007 a, Carrillo 2007 a, Carrillo 2007 b, de la Rosa 2007, Urban 1993). Today , agents are being extensively used to implement electronic markets and electronic auctions. Generally speaking, the design and implementation of multi-agent systems is an attractive platform for the convergence of various AI technologies. That is the underlying philosophy of the RoboCup competitions (for both robots and simulators), where teams of agents must display their individual and collective skills in real-time (Van 2000, Rahwan 2003).

3. Major Challenges and Research Directions

Multi-agent systems offer strong models for representing complex and dynamic real-world environments. For example, simulation of economies, societies and biological environments are typical application areas (Luck 2004, IST 2002, Endriss 2004, Li 2005, Rahwan 2003, Neumann 2003, Norman 2003, Lopardo 2007). The Figure 1 presents the trends and directions for applications in which typically many agents and services may be involved (Luck 2005).

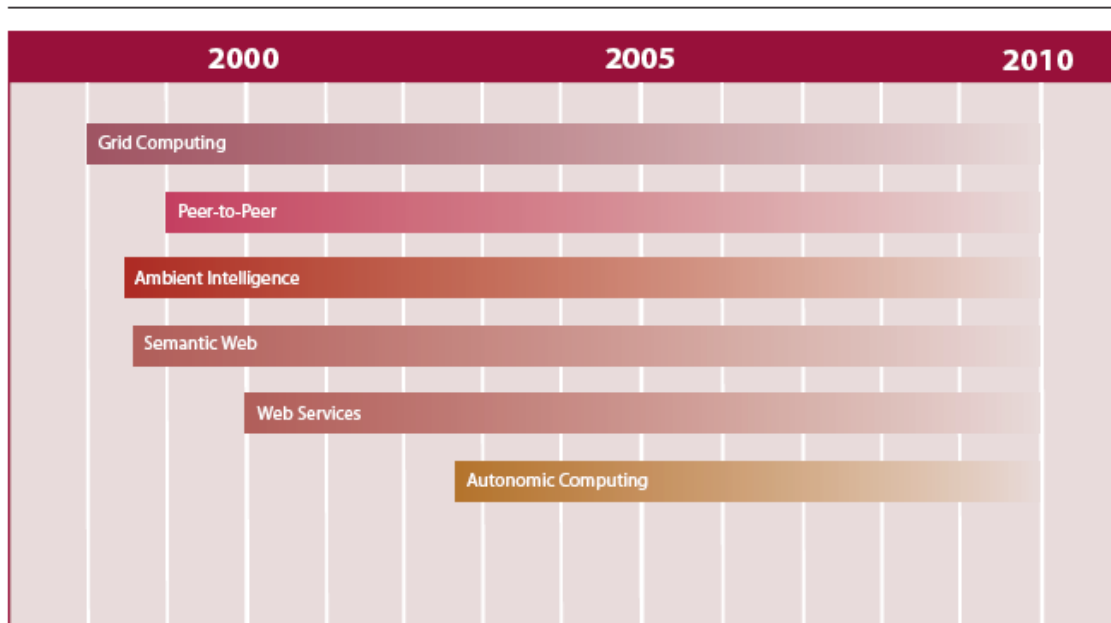


Figure 1: The emergence of agent-related domains over time (Luck 2005).

The European position on research and development in agent systems is healthy. There have been numerous active research groups in universities and research laboratories across

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Europe since the early days of the emergence of the field of agent-based computing as a distinct discipline, and the quality of work done is competitive at a global level. One reason for this is that since 1998, the European Commission has provided funding (albeit limited) to support the community through coordination projects, providing a focus and coherence to the community that might not otherwise have been possible (EC 2004).

Network Topology	No Standards	Single Standard	Two Standards
A: Disaggregated industry (non-connected nodes)	66.9	26.5	48.4
B: Disaggregated industry with peer relationships	66.7	26.8	48.7
C: Industry with shallow supply chains	25.0	17.6	22.1
D: Industry with deep, independent supply chains	76.5	26.6	49.1
E: Industry with deep, overlapping supply chains	67.6	19.8	48.7

Figure 1: Average numbers of generations to 100% adoption (by topology and numbers of standards) (Luck 2005)

It is still too early to consider the penetration of different industry sectors, but in a relative analysis of those domains that are likely to encourage the take-up and deployment of agent technologies, the Deliberative Delphi study (Munroe 2005) identified telecommunications and networks, manufacturing, transport and healthcare as the most significant over the next 5 years, 10 years and beyond. Participants were asked to select those in which they considered there would be likely deployment, with the results showing three broad classes. The second tier of domains includes: wholesale and retail trade; finance, insurance and real estate; computer software; public administration; and other utilities. The results are summarised in Figure 2, with all industry sectors represented, showing the number of times each was selected by participants over the different time periods

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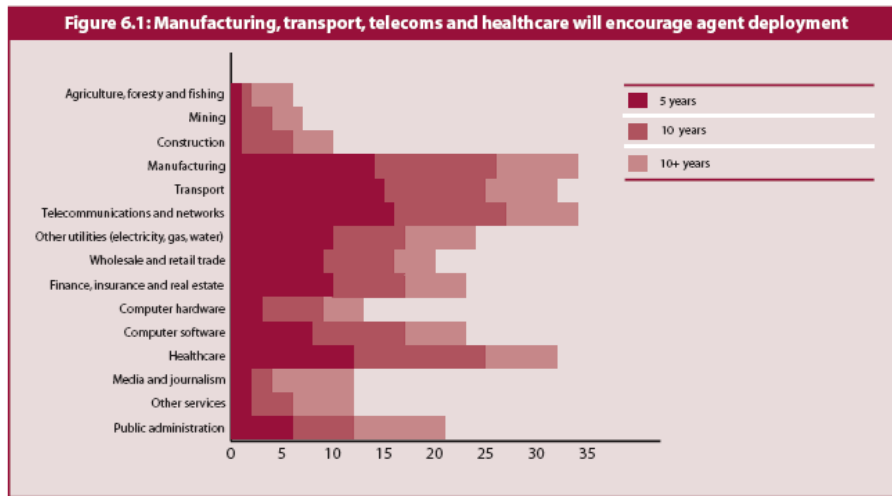
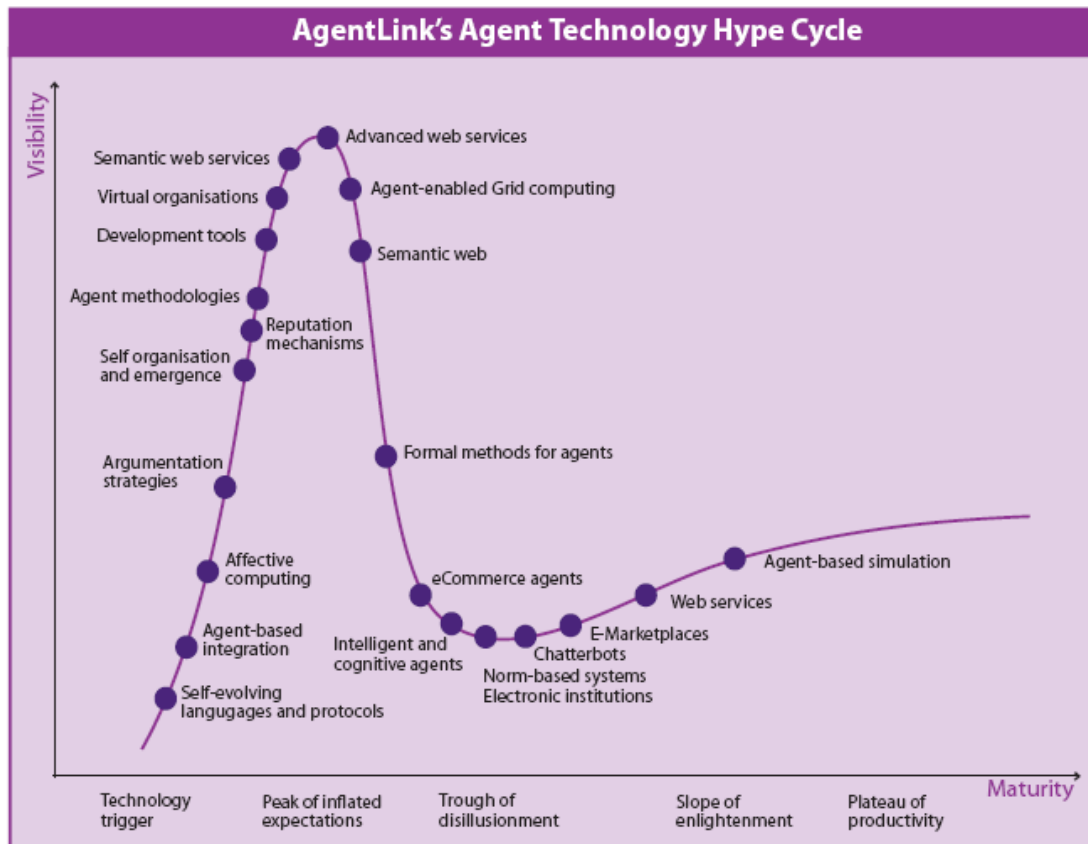


Figure 3: Manufacturing, transport, telecoms and healthcare will encourage agent deployment (Luck 2005)

Based on Gartner's analysis, (Gartner 2004a, Gartner 2004b) and a review from the AgentLink community, Luck (Luck 2005) has developed a complementary Hype Cycle for agent technologies, illustrated in Figure 3. Here, some technologies are seeing real deployed value across a range of applications. Increasingly, for example, agent-based simulation is being applied to logistics and other application domains, achieving clear and distinct results, with suppliers creating a space for themselves in this market niche. Similarly, web services are increasingly being used for the development of systems where there is a genuine understanding of the business benefits, rather than inflated and false expectations. However, many technologies are still to mature. Intelligent and cognitive agents, with sophisticated architectures, such as BDI, are situated in the trough of disillusionment, as are norm-based systems and electronic institutions, not yet finding roles in most mainstream business applications.

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Specific technical challenges continue to change as the field of agent-based computing advances and matures, and as related areas such as (Luck 2005, Westarp 2003):

- **Trust and reputation:** Sophisticated distributed systems are likely to involve action in the absence of strong existing trust relationships. While middleware addresses secure authentication, and there exist techniques for verification and validation, these do not consider the harder problems of establishing, monitoring, and managing trust in a dynamic, open system. As discussed earlier, we need new techniques for expressing and reasoning about trust and reputation, on both an individual and a social level to enable interaction in dynamic and open environments.
- **Virtual organisations (VOs)** have been identified as one of the key contributions of Grid computing, but principled and well-defined procedures for determining when to form new VOs, how to manage VOs and portfolios of VOs, how to manage competing and complementary VOs, and ultimately how and when to disband them, are still missing. Moreover, the development of procedures and methods for the automation of VO creation, management and dissolution also provide major research and development challenges.

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- **Resource allocation and coordination:** the coordinated, autonomic management of distributed resources requires new abstractions, mechanisms and standards in the face of multiple, perhaps competing, objectives from different stakeholders, and different definitions of individual and social welfare. Most R&D effort to date has focused on allocation and coordination mechanisms drawn from human societies (for example, common auction protocols), but the processing power and memory advantages of computational devices mean that completely new mechanisms and protocols may be appropriate for automated interactions, in particular for multi-objective coordination and negotiation. In addition, as with VOs, the automation of the design, implementation and management of mechanisms is a major challenge.
- **Negotiation** To date, work on negotiation has provided point solutions. There is a need for a solid theoretical foundation for negotiation that covers algorithms and negotiation protocols, while determining which bidding or negotiation algorithms are most effective under what circumstances. From the system perspective, behaviour arising through the interplay of different negotiation algorithms must be analysed, and determining what kind of negotiation to consider, and when, must be established. Finally, effective negotiation strategies and protocols that establish the rules of negotiation, as well as languages for expressing service agreements, and mechanisms for negotiating, enforcing, and reasoning about agreements are also needed. Incorporating capabilities for disagreement and justifications (i.e. arguments) in negotiations is also a major research challenge.
- **Emergence in large-scale agent systems:** while still relatively young, research in the area of emergent properties of large-scale agent systems offers insights from natural physical processes in the real world to better understand the dynamics of the increasingly large-scale artificial systems now being built. This approach views large-scale multi-agent systems as examples of complex, adaptive systems, which are the domain of the new discipline of complexity science. As this science matures, its focus on macro-scale properties of interacting entities may impact on the design, implementation and control of large-scale multi-agent systems. Approaches from physics, biology and other related fields provide different methods to model large scale systems, but it is not clear to what extent they are equivalent, and what each approach provides to software engineering or system control.

4. Towards agent and digital preservation

“Where is the agents” is the main topic in 2007, largely discussed by James Hendler (Hendler 2007) in his journal of IEEE Magazine on Intelligent Systems, his log, and afterwards in AAMAS congress in Hawaii: agents have so far failed to address the correct problems. There is no single application where agents provide with unique benefits or advantages compared to existing solutions. Digital preservation is a field with a lot of normative and rather much of isolated work, with heavy NIH syndrome (NIH – “non invented here”). To overcome this, there are coming to appear proposals based on software

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agents and web services (Hunter 2004, Anderson 2005). But, existing methods of digital preservation and curation are labour intensive and often require specialist skills. In this problem the applicability of Agents play an important role. Agent-based technology that facilitates preservation-friendly content production, transfer and ingest. Today, digital preservation has to take advantage of the web2.0 approach based on web services and the topics and research changes introduce in previous sections. This will allow the people cooperate for learning how and when preserve digital objects, where skilled people publish their expertise or answer questions of other people which use searchers or groups (like yahoo! answers). If this works, both individual and expert users (curators, preservators, public and private agencies) will work openly to provide all type of solutions, advice and resources (web services) to let objet preservation exist. The fact of having an open community sharing all type of resources (web services) and recipes for appraisal, format conversion, and digital preservation experiences is quite new in this community, and will provide lots of benefits. However, new problems may arise, especially with the overuse of experts, which will need further tools for automating their answers, to make on their behalf recommendations and resource and recipes exchange in proactive way: this is the real turn for agents.

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