

Editorial: Special Issue on Foundations, Advanced Topics and Industrial Perspectives of Multi-Agent Systems

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Abstract. This paper introduces the Special Issue of the journal of Autonomous Agents and Multi-Agent Systems on Foundations, Advanced Topics and Industrial Perspectives of Multi-Agent Systems. This special issue collects four articles dealing with some of the main issues that arose during the three Technical Forum Group meetings held in 2004 and 2005, which were organised and sponsored by the European FP6 Coordination Action AgentLink III.

1. Heritage of AgentLink: An Introduction

This editorial introduces the Special Issue of the Journal of Autonomous Agents and Multi-Agent Systems on *Foundations, Advanced Topics and Industrial Perspectives of Multi-Agent Systems*. This special issue collects four articles dealing with some of the main issues that arose during the three Technical Forum Group (TFG) meetings held in 2004 and 2005, which were organised and sponsored by the European FP6 Coordination Action AgentLink III. AgentLink III (2004-2005) was a European Union (EU)-sponsored project to support research and development in agent-based technologies and to strengthen Europe's efforts in this domain. It was funded under the Information Society Technologies (IST) Activity Area of the 6th Framework Programme (FP6), through the Semantic-based Knowledge Systems area (Project number: IST-FP6-002006CA).

1.1. A BRIEF HISTORY OF AGENTLINK III

AgentLink III successfully built on the work of its predecessors: the original AgentLink (1998-2001) project coordinated by Mike Wooldridge (then at Queen Mary & Westfield College, London, UK) – one of the “preparatory, accompanying and support measures” funded in the Long Term Research area of FP4 – was instrumental in promoting agent technology in European research and development. Under the coordination of Michael Luck (then at the University of Southampton, UK), the AgentLink II (2001-2003) FP5 “thematic network contract” was aimed at consolidating the European agent-oriented systems research community, and developed a high-quality tech-

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nological roadmap describing a vision for the future and potential of agent technology.

AgentLink III (2004-2005) was an FP6 “Co-ordination Action” led by Peter McBurney (University of Liverpool, UK) and Terry Payne (University of Southampton, UK), under the direction of a Management Committee including academic and industrial representatives from across the European agent technology community. To support this leadership, the project established in early 2004 a system of membership by which institutions active in agent research or development could apply to join the project. By the end of the project at 31 December 2005, 206 organisations from European Union member nations and associated states had become full members of AgentLink III, of which 134 were Universities, 32 were Research Institutes and 40 were private companies. A further 27 organisations were accepted as associate members, either because they were located outside Europe or because they are not yet active in agent research or development. This high level of membership indicated on the one hand considerable support for the project from European organisations, both public and private, on the other hand demonstrated widespread interest in agent-based technologies all across Europe.

1.2. GOALS OF AGENTLINK III

The long-term goal of AgentLink III was to put Europe at the leading edge of international competitiveness in the increasingly important area of agent technologies. In order to realise this aim, AgentLink III sought to achieve the following objectives:

- To gain competitive advantage for European industry by promoting and raising awareness of agent systems technology;
- to support standardisation of agent technologies and promote interoperability;
- to facilitate improvement in the quality, profile, and industrial relevance of European research in the area of agent-based computer systems, and draw in relevant prior work from related areas and disciplines;
- to support student integration into the agent community and to promote excellence in teaching in the area of agent-based systems;
- to provide a widely known, high-quality European forum in which current issues, problems, and solutions in the research, development and deployment of agent-based computer systems may be debated, discussed and resolved;

- to identify areas of critical importance in agent technology for the broader IST community, and to focus work in agent systems and deployment in these areas.

Further information about AgentLink III and its many activities is available from the AgentLink website at <http://www.agentlink.org>.¹

1.3. AGENTLINK III TECHNICAL FORA

In order to support co-ordination and collaboration of European research efforts, the main measure of AgentLink III, coordinated by Andrea Omicini (Università di Bologna, Italy), was to establish a series of research meetings – called the AgentLink III *Technical Fora* (TFs). Within each of these meetings, a number of parallel workshops – called *Technical Forum Groups* (TFGs) – were held on topics suggested in response to a call for proposals issued before each TF meeting. This ensured that the meetings reflected whatever was the current focus of research attention in the agents community. Also, this meant that the standard for acceptance could be quite high, with promoters asked to show evidence of research co-ordination activities before, during, and *beyond* each TF. Example outcomes of such activities included web sites and discussion forums, short and long reports of the Group meetings at the TF, surveys of activities, and co-authored survey papers of the field covered by the TFG.

Three TF events were held under AgentLink III:

- TF1: Rome, Italy: 30 June – 2 July 2004.
- TF2: Ljubljana, Slovenia: 28 February – 2 March 2005.
- TF3: Budapest, Hungary: 15 – 17 September 2005.

Over a hundred participants registered to attend each of the TF meetings, which all turned out as truly global events, with attendants not just from the European Union and affiliated countries, but also from the USA, Argentina, Dubai, Japan, and Australia.

Each TF supported six to nine TFGs, with many Groups meeting for multiple days. Because AgentLink sought to build links with related research disciplines as well as with other research projects, special effort was invested to encourage the formation of TFGs making connections between the agents community and other research communities. For instance, there were TFGs which looked at the intersection of agent technologies and: the law; biology

¹ We are grateful to the University of Southampton for continuing to host this web-site following the end of the project.

and bioinformatics; and economics. In addition, joint meetings were held by TFGs and two related EU-funded projects², *KnowledgeWeb* and *ASPIC*.

The discussions and contacts enabled by the AgentLink III Technical Forum Groups were very productive in generating new research and refereed publications. This output includes

- a special issue of the *Knowledge Engineering Review* journal (Omicini and McBurney, 2005), containing revised reports from selected TFGs at the 1st & 2nd AgentLink III TFs
- a double special issue of the journal *Informatica* “Hot Topics in European Agent Research II” (Omicini et al., 2005, Omicini et al., 2006), containing surveys and papers on hot topics in MAS research as emerging from 2nd AgentLink II TF held in Ljubljana
- a special issue of the journal *Autonomous Agents and Multi-Agent Systems* on “Environments for Multi-agent Systems” (Weyns and Parunak, 2007)
- a special issue of the *ACM Transactions on Autonomous and Adaptive Systems* on the AgentLink III TFs (Petta et al., 2007)

The present special issue of the journal *Autonomous Agents and Multi-Agent Systems* adds to this impressive list, and concludes the work by the AgentLink community.

2. About the Special Issue

The three AgentLink projects actually created the European space for research on agent technologies, building a community that still actively promotes agent-based approaches within a wide range of national and international research projects. The issue of the (present and future) impact of agent technologies outside research led to very animated discussions during many of the TFG meetings, and is still debated in the community. Discussions involved both technology aspects and foundational ones, and essentially paved the way toward this special issue. In fact, this issue contains four papers which together cover *foundations, advanced topics and industrial perspectives* of contemporary agent systems research and applications.

The theme of the adoption of technologies inspired by / resulting from agent research has been a recurring one in TFG meeting discussions. Speaking in general, this is not an original issue: any new technology has a life cycle, and a process for its spreading and adoption. The point here, however,

² See <http://knowledgeweb.semanticweb.org/> (FP6-507482) and <http://www.argumentation.org/> (FP6-002307).

is clearly whether agent-based technologies will *actually* become *successful* ones, or instead multi-agent systems (MAS) will remain confined within their research niche. In the first paper of this special issue, *Technology Diffusion: Analysing the Diffusion of Agent Technologies*, Jez McKean, Hayden Shorter, Michael Luck, Peter McBurney and Steven Willmott discuss the barriers to the large-scale adoption of agent technologies. After considering the role of standards in the diffusion of technologies, and their status in the agent landscape, the authors compare the diffusion of agent technologies with object-oriented ones, proposing a model allowing diverse diffusion trajectories to be evaluated based on different assumptions about industry structure and technology standards.

With respect to the early years of AgentLink, however, agent-based technologies have already found several ways to make into the industry. In the second paper, *Industrial Deployment of Multi-Agent Technologies: Review and Selected Case Studies*, Michal Pěchouček and Vladimír Marík provide an overview of the many application domains where agent-based technologies have been actually deployed, and present in-depth four case studies. Also, they list the key obstacles to the full exploitation of MAS in the industrial practice, and discuss some potential future challenges for industrial application of agent research.

Foundational issues have also traversed almost all TFGs in AgentLink III, and have finally led to many intriguing yet well-founded debates—way beyond the exasperating “What is an agent, then?” question. Since MAS are reaching a level of complexity that could be possibly compared to social and biological systems, a more articulated ontology than the mere “MAS are made of agents” is required for agent-oriented systems, accounting for notions like agent societies and MAS environment as first-class entities. So, in the third paper, *Artifacts for Agents in the A&A Meta-Model for Multi-Agent Systems*, Andrea Omicini, Alessandro Ricci and Mirko Viroli present a meta-model for MAS adopting agents and *artifacts* (A&A) as the basic bricks for MAS modelling and engineering. After discussing the many multi-disciplinary sources for the notion of artifact, they provide stipulative definitions for agents, artifacts and MAS, and show their application on different areas of agent research and technology

The same issues that led to the development of agent research have also produced other successful streams of research: among the other, Autonomic Computing is apparently among the most interesting ones. In the fourth and last paper of this special issue, *Autonomic Communication Services: A New challenge for Software Agents*, Raffaele Quitadamo and Franco Zambonelli take the standpoint of autonomic communication as a relevant emerging area, define its main concepts, and discuss the strict relation with agent-based models. In essence, they show how agent-based models and technologies have

the potential to play a major role in advancing the whole area of autonomic communication, and, more generally, of autonomic computing.

Altogether, the works collected in this special issues may be read as denoting a point of crisis for agent-based models and technologies, where foundations have to be reconsidered in order to capture the complexity of today MAS, technologies have to be fully developed in order to achieve widespread diffusion and industrial application, and other research fields apparently address similar issues and possibly solve problems of the same sort. At the same time, the four papers also provide long-term perspectives for the full exploitation of the results of research in the agent field, and clearly show how agent-based technologies could become successful ones, finally.

Whatever will actually happen in the future, the run of AgentLink has been a hugely successful experience from a scientific viewpoint, and its many results are likely to be here to stay.

3. Conclusions

The papers in this volume are the culmination of considerable work from TF organisers, presenters, authors, referees, and journal editors. We wish to thank the authors of the papers invited for this Special Issue for their patience in enduring such a long review process, which lasted nearly two years, and also the referees who took care to read and comment on these papers, constructively adding their contribution to the authors' one. The Special Issue could not have happened without these different efforts. In addition, we wish to thank all those who made the AgentLink III Technical Fora such noteworthy successes, especially the AgentLink III staff: Catherine Atherton, Becky Earl, Adele Maggs, and Serena Raffin. We would also like to thank the AgentLink III Management Committee for their efforts and their support, and the local organisers and their staff at each event: Rino Falcone at TF1, Matjaz Gams at TF2, and László Z. Varga at TF3. We also thank Cristiano Castelfranchi (TF1), who co-chaired the Technical Forum Committees with the editors of this special issue. Finally, we are grateful to the European Commission for the financial and other support received for the AgentLink III project (IST-FP6-002006CA).

We hope you enjoy reading this Special Issue!

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