

Semantic Web and Declarative Agent Languages and Technologies: Current and Future Trends (Position Paper)

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1 Introduction

One of the first discussions about a Web enriched with semantics and its relationships with artificial intelligence (and hence, with intelligent agents) dates back to 1998 [4], but it was only ten years ago that the idea of a Semantic Web on top of which agent-based computing would have allowed computer programs to interact with non-local web-based resources, became familiar to a wide audience of scientists [5, 10].

The integration of Semantic Web concepts as first class entities inside agent languages, technologies, and engineering methodologies has different levels of maturity: many AOSE methodologies, organizational models and MAS architectures seamlessly integrate them (for example, [20], [19], and the FIPA “Ontology Service Specification”, www.fipa.org/specs/fipa00086/, respectively), but few languages do.

In this position paper we review the state of the art in the integration of semantic web concepts in declarative agent languages and technologies and outline what we expect to be the future trends of this research topic.

2 State of the Art

Agent Communication Languages. In agent communication, the assumption that ontologies should be used to ensure interoperability had been made since the very beginning of the work on ontologies, even before they made the basis for the Semantic Web effort. Both KQML [15] and FIPA-ACL [9] allow agents to specify the ontology they are using, although none of them forces that. Agent communication languages were born with the Semantic Web in mind. The same does not hold for agent programming languages, that only recently started to address ontologies as first class objects.

Agent Programming Languages. AgentSpeak [17] underwent many extensions over time. However, what was considered only with the work [16] discussing AgentSpeak-DL, is that ontological reasoning could facilitate the development of AgentSpeak agents. The implementation of AgentSpeak-DL concepts is given in JASDL [12]. Cool-AgentSpeak [14], the “Cooperative Description-Logic AgentSpeak” language integrating Coo-BDI [1] and AgentSpeak-DL and enhancing them with *ontology matching capabilities* [8] is a further effort on this subject. The authors of [6] and [7] explore the use of a formal ontology as a constraining framework for the belief store of a rational agent and show the implementation of their proposal in the Go! multi-threaded logic programming language [6]. We are not aware of similar attempts made with non-declarative ones, apart from the support that JADE [3] offers to ontologies, which is limited to boosting agent communication by allowing the agents to refer to concepts belonging to ontologies in the messages they exchange, and is hence due to the respect of FIPA-ACL specifications.

Proof and Trust in MASs. Even if the Semantic Web is often incorrectly reduced to reasoning on semantic markups, it actually goes far beyond that, coping with proof and trust as well. Both these topics are extremely hot within the agent community, and on the DALT’s one in particular. In the literature we can find dozens of works on trust and reputation in agent societies, and research on formally proving that an agent can enter an organization without damaging it has already produced many valuable results. Model checking declarative agent languages has a long tradition too (see for example the “MCAPL: Model Checking Agent Programming Languages” project, http://cgi.csc.liv.ac.uk/MCAPL/index.php/Main_Page, and [11]).

3 Future Trends

There are many promising directions that the research on integration of Semantic Web technologies and DALTs could take.

Semantic-Web based Proof and Trust. Although the maturity level of the aspects concerned with proof and trust in DALTs is satisfactory, mechanisms that give the developer the real power or putting all together are still missing. For example, to design and build MASs where agents can trust each other, the consistency of the agents’ beliefs represented as ontologies should be always preserved, and formally demonstrated if required by the application.

Semantic-Web based Mediation. In [2], a semantic mediation going beyond the integration of ontologies within traditional message-based communication was envisaged. Mediation should occur at the level that characterizes the social approach where it is required to bind the semantics of the agent actions with their meaning in social terms (ontology-driven count-as rules).

Semantic Representation of the Environment. Although not yet formalized in published papers, the A&A model [18] is moving towards integrating semantic web concepts as first class objects for semantically representing the environment and the artifacts available to the agents¹. This line of research should be pursued by other declarative approaches as well, where the environments is explicitly represented. Formally proving the consistency of the “Environment Ontology” should be possible, as well as evolving it, and learning it from sources of semi-structured information.

Adoption of Semantic-Web enriched DALTs for Real Applications. Many real applications involve scenarios where procedural rules for achieving a goal are expressed in an informal and fully declarative way, may require to achieve sub-goals, and the domain knowledge is hard-wired within the rules themselves, making them barely re-usable in other domains, even if they could. Think of the rules for getting a new identity card issued by Genova Municipality, which are declaratively defined by conditions to be met, other documents to be obtained before, and exactly the same as those for obtaining the document in another municipality, but nevertheless would be hard to compare. Expressing procedural rules of this kind using declarative agent languages fully integrated with semantic web concepts might help comparing and composing them in an automatic way, moving a step forward the automation of many services that are still completely performed by human agents.

Discussion. The first problem that the Semantic Web and Declarative Agent Languages and Technologies communities should struggle to solve together, is bringing usability to the world. Forthcoming technologies should be not only secure, efficient, self-*, etc. It is mandatory that *they will be usable* by average computer scientists, average professionals and even average users. “*Making intelligent software agents both powerful and easy to construct, manage, and maintain will require a very rich semantic infrastructure*” [13], and the rich semantic infrastructure seething with agents, must be there for anyone. In a few years, it must become a commodity, clearing the boundaries of academic research once and for all.

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¹ Private communication of one of the authors of this paper with the authors of the A&A model.

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