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Olivier Boissier

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Multi-Agent Oriented Programming as a Means to Bring Agents on the Web

Olivier Boissier (*Ecole des Mines – St. Etienne, FR*)

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Joint work of Rafael H. Bordini, Jomi Fred Hübner, Aleassandro Ricci, Andrei Ciortea

The Web is pervasive, increasingly populated with interconnected data, services, people and things [6]. As stated in [7], the Web is the middleware of choice for most distributed systems, where hypermedia turns into a homogeneous information fabric that interconnects everything — devices, information resources, abstract concepts, etc. Clients are not only able to browse and query, but also to observe and act on this hypermedia fabric, transforming the Web in a sophisticated *social machine* [3]. The next step, which has been awaited for a long time, consists in bringing in this global ecosystem, autonomous agents, entities able to react to events while pro-actively defining goals and directing actions to achieve them. Using this hypermedia fabric in a flexible and autonomous manner, agents will build hybrid communities on the Web [2], where they will help people cope with the growing number of available resources, and achieve increasingly complex collaborative tasks.

Research on Multi-Agent Systems (MAS) has led to the development of several models, languages, and technologies for programming not only agents, but also their interaction, the application environment where they are situated, as well as the organisation in which they participate. Research on those topics moved from Agent-Oriented Programming towards Multi-Agent Oriented Programming (MAOP)[1]. A MAS program is then designed and developed using a structured set of concepts and associated first-class design and programming abstractions that go beyond the concepts normally associated with agents. They also include those related to environment, interaction, organisation. As an example of such an approach, JaCaMo is a platform for MAOP[5]. It is built on top of seamlessly integrated dimensions (i.e. structured sets of concepts and associated execution platforms): for programming BDI agents, their artifact-based environments, and their normative organisations. The key purpose of JaCaMo is to support programmers in exploring the synergy between these dimensions, providing a comprehensive and clear programming model, as well as a corresponding platform for developing and running collective autonomous systems.

In this presentation, our claim is that the MAOP framework could serve as the foundations for bringing agents on the Web [4]. Such an approach proposes programming concepts useful to engineer autonomous software agents, to balance reactive and goal-directed behavior in software agents, to define social agents that are able to interact with other agents, to govern

their autonomous behavior while evolving under different organisations, norms and policies. By providing environment concepts as first-class entities, it opens new perspectives on the conceptual integration between MAS and the Web in which the Web becomes visible and uniformly accessible to the agents. It could become a place for stigmergic interactions among agents on the Web, that can be programmed for the agents as it is programmed for the people. Web resources are first class abstractions situated in the agent's environment as well as in the digital environment of people. Finally, the organisation concepts as first class abstraction open perspectives to provide the means to govern such hybrid communities on the Web. The Web being visible and accessible as the shared environment in which agents act, it may become the entry point for monitoring the actions on the resources of both the autonomous agents and the people, for monitoring the interactions in these hybrid communities. Thanks to organisation as first-class abstraction, governance and social enforcement mechanisms, external to the agents, could then allow to control and regulate the autonomous social behavior of agents.

However, even if this is the first step to bring agents in such hybrid communities on the Web, having a world-wide scale, open and long lived eco-system, requires still to consider several challenging issues.

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