Multiagent Systems in the Web

Hércules Antonio do Prado
Brazilian Enterprise for Agricultural Research and Catholic University of Brasília, Brazil

Aluizio Haendchen Filho
Anglo-Americano College, Brazil

Míriam Sayão
Pontifical Catholic University of Rio Grande do Sul, Brazil

Edilson Ferneda
Catholic University of Brasília, Brazil

INTRODUCTION

The rapid evolution of Internet has opened a new era in the distributed systems scenery: the bigger part of the information systems currently developed is focused in Web applications. Typically, the information resources in Web systems are dynamic, distributed, and heterogeneous. Since these computing environments are opened, information resources can be connected or disconnected at any time. This ubiquity of Web and its distributed and interconnected characteristics represent a natural field for multiagent systems (MAS), spreading this kind of application. Software agents can dynamically discover, orchestrate, and compose services, check activities, run business processes, and integrate heterogeneous applications.

Most of the large organizations adopt heterogeneous and complex information systems. These systems must coordinate their applications in order to provide efficient support to business processes and consistent information management. Unfortunately, the operational software underlying these systems usually does not handle multitask distributed heterogeneous applications. Currently, enterprises are strongly interested in the strategic advantages of adopting distributed infrastructures that are designed to be dynamic, flexible, adaptable, and interoperable. In this context, the demand for agent-based applications has increased, opening new types of applications that include e-commerce, Web services, knowledge management, semantic Web, and information systems in general. Interesting solutions to B2B (business to business), e-business, and also applications that require interoperability based on knowledge about applications and business processes, will definitely benefit from the MAS technology. Also, intelligent information agents are regarded as one of the most promising areas for applying agents' technology. Intelligent information agents act in fields like collaborative systems on Internet, knowledge discovery from heterogeneous sources, systems for intelligent management of information, and so on. The Web can also be seen as a big distributed database having XML (extensible markup language) and its extensions or modifications as an underlying data model.

In this context, the MAS development has received support from new tools in order to make it easier for the developer to cope with specific requirements for Web architectures. It is accepted that these improvements in the technology, mainly by the new tools that are becoming available, will lead MAS technology to be explored in its full potential. So, we can state that the application domain of MAS is going to be strongly enlarged, defining a turning point in the systems development activity.

In this chapter, we provide an overview on MAS technology, discuss how this technology is impacting the Web context, and provide a sound description of the concepts that are relevant to the application developers and target users.

BACKGROUND

The adoption of agents' technology in distributed and concurrent systems derives from the idea that cooperation, flexibility, and intelligence of agents can contribute significantly to improve the overall performance and quality of information systems. An agent-based system is composed of autonomous computational entities that possess individual capabilities and goals, and can be grouped to work cooperatively, aiming to reach the system objective. There is not a universally accepted definition to the term "software agent." Wooldridge *et al*. (Wooldridge, Jennings, & Kinny, 1999) explains that this difficulty is partially due to the fact that, for each different application domain, the properties assigned to the agent concept take several important levels, therefore, it is possible to find many types of software agents with different

characteristics, such as mobility, autonomy, collaboration, persistence, and intelligence. The agents' behavior depends on, and is affected by, their properties. Based on previous studies carried by Kendall *et al.* (Kendall, Krishna, Pathak, & Suresh, 1999), the OMG (object management group) (2000), and Garcia *et al*. (Garcia, Silva, & Lucena, 2001) describe the following properties for software agents:

1. Interaction: an agent communicates to the environment and to other agents by means of *sensors* and *actuators*.
2. Adaptation: an agent must self adapt its state and behavior according to the environmental conditions.
3. Autonomy: an agent possesses its own control thread and can accept or refuse a request. Autonomy is understood as the agent capabability to perform its activities independently from the human intervention.
4. Capacity to learn: an agent can learn based on previous experiences when interacting with its environment.
5. Mobility: an agent must be able to transfer itself from one environment to another in order to achieve its goals.
6. Collaboration: an agent can cooperate with other agents in order to achieve its objectives and the system objectives.

According to OMG (2000), autonomy, interaction, and adaptation can be considered fundamental properties of software agents, while capacity to learn, mobility, and collaboration are not strictly required properties to characterize agents. There is a consensus in the literature that autonomy is the key property for an agent. Agents must present, at least in some extension, independence. They are not completely preprogrammed, but can take decisions based on information from other agents or from the environment.

Ferber (2000) argues that an agent can be defined from the agency characteristics as a physical or a virtual entity, with the following properties or abilities:

- is capable to act in an environment;
- can communicate to other agents;
- is driven by a set of tendencies as individual goals;
- possesses its own resources;
- is capable to perceive its environment (in a certain extension);
- possesses only a partial representation of the environment;
- possesses abilities and can offer services;
- can be able to replicate itself;
- its behavior is driven by its goals, considering the amount of resources and abilities available, and depends on its environmental perception and the messages it receives.

By this definition, an agent can *act,* not only *reason,* and the effect of its actions in the environment can affect future decisions. There are a number of different criteria to classify agents in the literature. For example, Jennings *et al*. (Jennings, Atighetchi, Vincent, & Lesser, 1996) state that to act autonomously, agents must present the following abilities: perception, capacity to belief-based reasoning, to decision taking, and to plan, and ability to execute these plans, including message carrying. Jennings *et al.* (1996) categorize agents according to their levels to solve problems in the following types:

Figure 1. Multiagent system structure