



Integrating Intelligent Mobile Agents with Web Services

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ABSTRACT

*Research on Web services aims at extending the Web with computer-understandable descriptions enabling programs to interact and exploit Web-accessible programs without human intervention. Advances in this line of research will strongly benefit the fields of intelligent and mobile agents due to their potentials for building Web-enabled applications. In this paper, we describe a novel programming language called *MoviLog* for developing intelligent mobile agents that interact with Web services. The most interesting aspect of the language is its *Reactive Mobility by Failure* mechanism that allows programmers to develop mobile agents without explicitly providing code for handling mobility.*

Keywords: logic programming; mobile agents; Web applications; Web services

INTRODUCTION

Many researchers envision the Web of the future as a global community, where people and intelligent agents interact and collaborate (Hendler, 2001). Unfortunately, today's Web has been designed for human interpretation and use (McIlraith et al., 2001), generally for reading and browsing HTML (Hyper Text Markup Language) pages and online form filling. However, there is a need for automating the interoperability of B2B (business-to-business) and e-commerce applications. Until now, this interoperation has been handled by using programs that interact with Web-

accessible services to obtain and then parse HTML content for extracting data. This approach is very weak, since it depends on the format of the HTML pages and interfaces such as CGI (Common Gateway Interface) or RMI (Remote Method Invocation) for accessing services. In order to achieve a truly automatic interoperability between programs and Web-accessible resources, new technologies aim at creating a *Semantic Web* (Berners-Lee et al., 2001), where information and services offered by every site are described in a non-ambiguous and computer-understandable way.

In the scenario of the Web consisting of sites with highly dynamic content, mo-

bile users, unreliable links, and small portable devices such as PDAs (Personal Digital Assistants) and cellular phones, mobile agents will play a fundamental role (Hendler, 2001). A mobile agent is a computer program that represents a user in a computer network and is able to migrate autonomously from site to site to perform tasks on behalf of the user (Tripathi et al., 2002). This feature is particularly interesting when an agent makes sporadic use of a valuable shared resource located at a remote site. In addition, efficiency can be improved by moving agents to a host to query large repositories and then return with the results, thus avoiding multiple interactions with the data over network links subjected to delays or interruptions of services.

Mobile agents exhibit a number of properties that make them suitable for exploiting the potential of the World Wide Web (WWW), because they add mobility (the capacity to migrate across sites of a network) (Fuggetta et al., 1998) to the capacities of ordinary intelligent agents (reaction, perception, deliberation, autonomy, etc.). Some of the most significant advantages of mobile agents are their support for disconnected operations, heterogeneous systems integration, robustness, and fault-tolerance (Milojicic et al., 1999; Lange & Oshima, 1999).

Despite the number of applications that can benefit from the usage of mobile agents (Kotz & Gray, 1999), this technology has shown difficulties when used for interacting with Web content (Hendler, 2001). An agent's inability to understand concepts required for invoking and using Web-accessible services and resources requires the creation of a semantic Web, where its content is described according to precise semantics. In this sense, we claim that there is a need for a mobile agent development tool for solving these problems,

which, at the same time, preserves the key benefits of mobile agent technology.

A step toward the widespread adoption of mobile agents is *MoviLog* (Zunino et al., 2002). *MoviLog* is a platform for building Prolog-based (Clocksin, 1994) intelligent mobile agents for the WWW that provide a novel mechanism for handling mobility-named RMF (Reactive Mobility by Failure). This mechanism allows the programmer to exploit the advantages of mobility without explicitly programming mobile code.

In order to take advantage of the features of mobile agents for building Web applications, we have extended *MoviLog* to invoke Web services. This offers an exceptional opportunity for building distributed applications based on intelligent mobile agents that access Web information and resources in an automatized form. For example, it will be possible to automatize classic e-commerce applications such as e-shops, e-malls, and e-actions, allowing automatic interaction between participating entities at both sides of each transaction along with minimal programming effort.

This paper is structured as follows: the next section introduces Web services and the Semantic Web. Next, *MoviLog* is introduced briefly. Then we explain our approach for integrating *MoviLog* and Web services. After that, an agent implemented with *MoviLog* is presented. Finally, we describe the most relevant related work and conclude.

WEB SERVICES AND THE SEMANTIC WEB

Unlike the current WWW, Web services (Vaughan-Nichols, 2002) (i.e., Web accessible programs and devices) can be seen as a set of programs interacting in a

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