ABSTRACT

In this article, we present the software architecture of a new generation of advisory systems using Intelligent Agent and Semantic Web technologies. Multi-agent systems provide a well-suited paradigm to implement negotiation processes in a consultancy situation. Software agents act as clients and advisors, using their knowledge to assist human users. In the presented architecture, the domain knowledge is modeled semantically by means of XML-based ontology languages such as OWL. Using an inference engine, the agents reason, based on their knowledge to make decisions or proposals. The agent knowledge consists of different types of data: on the one hand, private data, which has to be protected against unauthorized access; and on the other hand, publicly accessible knowledge spread over different Web sites. As in a real consultancy, an agent only reveals sensitive private data, if they are indispensable for finding a solution. In addition, depending on the actual consultancy situation, each agent dynamically expands its knowledge base by accessing OWL knowledge sources from the Internet. Due to the standardization of OWL, knowledge models easily can be shared and accessed via the Internet. The usefulness of our approach is proved by the implementation of an advisory system in the Semantic E-learning Agent (SEA) project, whose objective is to develop virtual student advisers that render support to university students in order to successfully organize and perform their studies.

Keywords: agents; e-learning; ontology; Semantic Web application

INTRODUCTION

E-learning has started to play a major role in the learning and teaching activities at institutions of higher education worldwide (Hamdi, 2006). Students perform significant parts of their study activities decentralized via the Internet. The main focus of current e-learning systems is to provide an appropriate technical infrastructure for content engineering and information exchange.
The emerging trends in individual ways of study are location- and time-independent, consequently requiring a permanently available and direct support in order to answer questions and give advice. A recent comparison of modern e-learning environments (CCTT, 2004) revealed that intelligent advisory agents are not applied so far in e-learning systems.

The objective of the Semantic E-learning Agent (SEA) project (Dunkel, Bruns, & Ossowski, 2004) is to develop virtual student advisers that render support to university students, assisting them to successfully organize and perform their studies. The experiences of human course advisers show that most students have similar problems and questions. The advisory agents should help to resolve these problems. Typical questions concern the regulations of study (e.g., does a student possess all requirements to participate in an examination or a course?) or organizing student mobility.

To achieve these goals, we propose a software architecture of an advisory system in which virtual student advisers are developed with novel concepts from the Semantic Web (Berners-Lee, Hendler, & Lassila, 2001; Horrocks & Hendler, 2002) and Intelligent Agent (Wooldridge & Jennings, 1995) technologies.

The Semantic Web can be defined as an “extension of the current web in which information is given well-defined meaning” (Berners-Lee et al., 2001). The basic idea is to represent domain data and their structure in a well-defined and machine-interpretable way. For this purpose, ontology languages based on XML and RDF/RDF Schema (W3C-RDF, 2004) are defined. The W3C consortium announced the standard ontology language OWL (Web Ontology Language) (W3C-OWL, 2004). Ontology languages allow the explicit formal specification of the entities in a domain and the relations among them. They can encode the knowledge accessible on different Web sites making it understandable for computer programs.

One essential aspect of our proposed software architecture is to model the structure of the e-learning domain by means of ontologies and to represent it by XML-based ontology languages. Software agents apply the knowledge represented in the ontologies during their intelligent decision-making process. We claim that this is a promising approach, because e-learning systems that successfully support students in organizing their studies are still to come. This article reports on the experiences gained from the development of an advisory system architecture that effectively integrates both Semantic Web and intelligent agent technologies.

The first use case that has been implemented reflects the counseling situation in which a student intends to study a semester abroad within the European Socrates/Erasmus exchange program. Together with the international coordinator, the student has to choose the foreign university and the foreign study program that best matches his or her personal interests and his or her situation of study. Subsequently, a study plan for the semester at the host university must be determined that corresponds to the home university syllabus. This study plan constitutes the so-called Socrates Learning Agreement.

The remainder of this article is structured as follows. In the next section the knowledge representation techniques and the knowledge models developed are presented. The next section shows how automated inference can be carried out on the knowledge models. Subsequently,
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