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About Whitestein Technologies

Whitestein Technologies AG was founded in 1999 with the mission to become a leading provider of advanced software agent technologies, products, solutions, and services for various applications and industries. Whitestein Technologies strongly believes that software agent technologies, in combination with other leading-edge technologies like web services and mobile wireless computing, will enable attractive opportunities for the design and the implementation of a new generation of distributed information systems and network infrastructures.

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Ontologies for Agents: Theory and Experiences

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Contents

Foreword

There is a growing interest in the use of ontologies for multi-agent system applications. On the one hand, the agent paradigm is successfully employed in those applications where autonomous, loosely-coupled, heterogeneous, and distributed systems need to interoperate in order to achieve a common goal. On the other hand, ontologies have established themselves as a powerful tool to enable knowledge sharing, and a growing number of applications have benefited from the use of ontologies as a means to achieve semantic interoperability among heterogeneous, distributed systems.

In principle ontologies and agents are a match made in heaven, that has failed to happen. What makes a simple piece of software an *agent* is its ability to communicate in a "social" environment, to make autonomous decisions, and to be proactive on behalf of its user. Communication ultimately depends on understanding the goals, preferences, and constraints posed by the user. Autonomy is the ability to perform a task with little or no user intervention, while proactiveness involves acting autonomously with no need for user prompting. Communication, but also autonomy and proactiveness, depend on knowledge. The ability to communicate depends on understanding the syntax (terms and structure) and the semantics of a language. Ontologies provide the terms used to describe a domain and the semantics associated with them. In addition, ontologies are often complemented by some logical rules that constrain the meaning assigned to the terms. These constraints are represented by inference rules that can be used by agents to perform the reasoning on which autonomy and proactiveness are based.

In practice, the application areas of these technologies often overlap, for example: e-commerce, intelligent information integration, and web services. Increasingly, the multi-agent systems and ontology research communities are seeking to work together to solve common problems. A key focus to this joint working is emerging in ideas for the semantic web. Both ontologies and agent technologies are central to the semantic web, and their combined use will enable the sharing of heterogeneous, autonomous knowledge sources in a scalable, adaptable and extensible manner.

This volume collects the most significant papers of the AAMAS 2002 and AAMAS 2003 workshop on ontologies for agent system, and the EKAW 2002 workshop on ontologies for multi-agent systems. The workshops were taking different perspectives to the topic of using ontologies in the framework of a multi-agent system. On the one hand, there is the knowledge modelling perspective; *i.e.* how ontologies should be modelled and represented in order to be effectively used in agent systems. On the other hand, there is the agent perspective; what kind of capabilities should be exhibited by an agent in order to make use of ontological knowledge and to perform efficient reasoning with it.

The volume aims at providing a comprehensive review of the diverse efforts covering the gap existing between these perspectives. The papers cover a wide range of topics but can mainly be grouped in three categories: modelling principles

for building and reasoning with ontologies for agents, semantic interoperability between different agents, and applications of ontologies in agent systems.

Modelling ontologies entails dealing with the problems of building ontologies, and establishing ontological commitment. Semantic interoperability includes reasoning with ontological knowledge that agents may use to proactively overcome differences in their conceptualisation of the world, and applications of ontologies concern real life examples of how ontologies can be used in agents.

For what concerns modelling and representing ontologies, Cranefield and colleagues in their first contribution propose to reduce the degree of human interpretation currently necessary to understand an interaction protocol, by describing at an abstract level the required agent actions that must be 'plugged into' the protocol for it to be executed. In particular, this can be done by designing and publishing ontologies describing the input and output data that are processed during the protocol's execution, together with the actions and decisions that the agents must perform.
Nodine and Fowler concentrate on ontological commitment, or the agreement to have applications and users conform to a common domain understanding, as encapsulated in one or more shared ontologies. They present their experiences in building ontology-based agent systems in multiple domains and illustrate the problems arising when a new application aims to locate and conform to some existing ontology or ontologies within its domain. The authors propose guidelines for ontology development and evolution, which should facilitate ontology reuse that may underpin a *usage model* for ontologies; one that enables the application designer to reuse ontological concepts from multiple ontologies in a more flexible manner, while retaining the essentially good properties of ontology sharing and reuse.
Pazienza and Vindigni also concentrate on ontological commitment, and in particular, on the lack of a shared knowledge model that can be assumed as a default *ontological commitment*. They propose a communication model based on the use of natural language, that predicates a strong separation among terms and concepts. In order to support the proposed communication model, the authors present a novel agent architecture able to deal with possible linguistic ambiguities by focusing on the conversational level.

An important part of this volume is devoted to approaches aimed at finding an ontological model that is shared by all the agents composing a system. These approaches become particularly important when agents commit to heterogenous ontologies. Dou and colleagues present an approach to ontology translation, one of the hardest problems agents must cope with. In their approach, the merging of two related ontologies is obtained by taking the union of the terms and the axioms defining them. Bridging axioms are added, not only as bridges between terms in two related ontologies, but also to make this merge into a completely new ontology, which can subsequently be merged with other ontologies. Translation is implemented using an inference engine (OntoEngine), running in either a demand-driven (backward chaining or data-driven (forward chaining) mode.

Leen-Kiat Soh contribution describes a multiagent framework for collaborative understanding of distributed ontologies. The framework aims to investigate and identify how agents collaborate to understand each other under resource constraints and operational setups, and to examine how agents manage and share their distributed ontologies triggered by various queries. To facilitate collaborative understanding, each agent maintains an ontology and a translation table with other agents or neighbors.
In Lister and colleagues, the authors address the problem of semantic interoperability on the web, and present their research experiments suggesting that as yet unaddressed issues should be considered; such as reconciling implicit ontologies, evolving ontologies, and task-oriented analysis. The authors consider the role of semantic interoperation in multi-agent systems, and describe strategies for achieving it via the ROADMAP methodology.
Stuckenschmidt and colleagues concentrate on the problem of answering queries over multiple data sources in a dynamic environment, where it is no longer realistic to assume that the involved data sources act as if they were a single (virtual) source, modelled as a global schema. In their contribution, they propose an alternative approach where they replace the role of a single virtual data source schema with a peer-to-peer approach relying on limited, shared (or overlapping) vocabularies between peer agents.
Chris van Aart and colleagues present an approach to agent communication, based on message content ontologies that specify the meaning and intention of messages. By committing to a shared ontology, several agents can reach an agreement on different agent communication languages.

With respect to applications, Annamalai and Sterling investigate the possibility for agent systems aiding with collaboration among Experimental High-Energy Physics (EHEP) physicists. They argue that a necessary component is an agreed scientific domain ontology, which must include concepts that rely on mathematical formulae involving other domain concepts, such as energy and momentum. In this work, previous efforts on representing mathematical expressions are adapted to produce a set of representational primitives and supporting definitions for modelling complex mathematical relations.
Chen and colleagues investigate the use of ontologies in a multi-agent system providing brokering services for pervasive computing. Cranefield and colleagues, in their second contribution, propose the use of a UML profile for ontology modelling, to represent an ontology for travel booking services, and automatically derive an object-oriented content language for this domain. This content language is then used to encode example messages for a simple travel booking scenario, and it is shown how this approach to agent communication allows messages to be created and analysed using a convenient object-oriented, agent-specific application programmer interface. Dickinson and Wooldridge present a belief-desire-intention (BDI) approach to the problem of developing an agent-assisted travel scenario, and ask what role ontologies would have in supporting the agent's activity. To

this end, their contribution discusses the Nuin agent platform, and illustrates various ways in which ontology reasoning supports BDI-oriented problem solving and communications by the agents in the system.
Sashima and colleagues focus on the problem of achieving coordination in ubiquitous computing, and in particular. bridging the coordination gap separating devices, services, and humans. They propose an agent-based coordination framework for ubiquitous computing to solve this human-centered service coordination issue.
Zimmerman and colleagues present agent-based supply chain monitoring system for tracking orders, in which communication is enabled through the definition of a shared ontology. The paper discusses the design of the ontology and its use for inter-agent communication is illustrated with the help of AUML models of the agent-interactions in the supply chain monitoring system.

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