Ontology based agent system

Dejan Lavbič, Aljaž Zrnec

ABSTRACT

Today not only for enterprises but also for medium and small companies business decisions do not rely exclusively on organisation's internal data but also on external data from competitors or what is even more important data from relevant events in the environment. This data can be obtained from the Web and integrated with data in organisation's Data Warehouse (DW). In this paper we discuss agent-based approach for data integration using ontologies. To enable common understanding of a business domain between people and application systems we introduce business rules approach towards ontology management. Because knowledge in organisation's ontologies is acquired from business users without technical knowledge simple user interface based on ontology restrictions and predefined templates are used. After data from different sources are acquired, agent can deduce new knowledge and therefore facilitate decision making process. Tasks like information retrieval from competitors, creating and reviewing reports are autonomously performed by agents, while business users have control over their execution through knowledge base in ontology. The approach presented in the paper was verified on the case study from the domain of medium size construction companies where we also proposed to use cloud computing to reduce operational costs.

Key Words*: agent, intelligent agent, ontology, business rules, data warehouse, information retrieval, cloud computing*

1 INTRODUCTION

There is a growing recognition in the business community about the importance of knowledge as a critical resource for organisations. The purpose of knowledge management is to help organisations create, derive, share and use knowledge more effectively to achieve better decisions, increase of competitiveness and fewer errors. In order to run business more effectively an organisation needs intelligence about competitors, partners, customers, and also employees as well as intelligence about market conditions, future trends and much more. There are several products and technologies available on the market that support advanced Business Process Management. Organisations expect these applications to support wide range of functionalities – building and analysing business strategies, developing customer-specific services, carrying out targeted marketing and predicting sales trends. Several applications within information system that support wide range of functionalities need to be integrated in order to provide the appropriate level of information support. One of the prominent approaches for information system integration is the use of ontologies and Multi-Agent Systems (MAS).

The MAS consists of a collection of autonomous agents that can define their own goals and actions and can interact and collaborate among each other through communication. In a MAS environment, agents work collectively to solve specific problems. The stream of research on business information systems and enterprise integration (Lei, et al. 2002, Kang and Han 2003, Tewari, et al. 2003) makes the MAS paradigm a very appropriate platform for integrative decision support within business information systems.

Today, semantic technologies based on ontologies and inferencing are considered as a promising means towards the development of the Semantic Web. In information science, ontology is a knowledge model that describes a domain of interest using semantic aspects and structure. The approach presented in this paper is targeted towards using ontologies for several tasks, where emphasis is on using business rules approach for interoperability between business user and information system. The use of ontologies in MAS environment enables agents to share a common set of concepts about contexts, user profiles, products and other domain elements while interacting with each other. The purpose of this paper is to present integration of several information resources for Decision Support in Enterprises using agent-oriented approach based on ontologies. The goal of our research was to minimize the gap between business users and intelligent agents as special type of application systems that perform tasks in their behalf. The intention was to apply business rules approach for ontology manipulation in MAS. Ontology used in our Multi-Agent System for Decision Support in Enterprises (DSS-MAS) was divided into different task and domain ontologies while business users were enabled to manipulate with them directly in a user friendly environment without requirement of detailed technical knowledge. We also prososed to use cloud computing as an option to reduce operational costs. We used one of the commercial cloud for storing large amount of data and complex OLAP processing.

The remainder of this paper is structured as follows. First we present introduction and background. Next, in section 2, we introduce our case study of integrated Multi-Agent environment from the domain of medium size construction companies. After presentation of architecture and decomposition of ontology every agent from DSS-MAS will be presented. An overview of our approach to implementation of prototype will be given in section 3. In section 4 we present a preposition of using cloud computing for minimazing operational costs. Finally the last section presents conclusions and plans for future work.

2 INTEGRATED MULTI-AGENT ENVIRONMENT

Multi-Agent System for Decision Support in Enterprises (DSS-MAS) that we propose in this paper is introduced in Figure 1. The case study presented in this paper is from the domain of construction companies and is based on business environment and information resources from one of the mobile operators. DSS-MAS is situated in the environment with several existing systems, from Data Mining Decision Support System (DMDSS), to Data Warehouse (DW) and various resources outside the organisation available on the World Wide Web.

Global goal that agents in DSS-MAS strive to is supporting decision making process while using existing systems for business analysis in organisation and employing information from environment where organisation resides. To support this goal DSS-MAS includes several agent roles as following: Data Mining Agent (DMA), OLAP Agent (OLAPA), Information Retrieval Agent (IRA), Knowledge Discovery Agent (KDA), Notifying Agent (NA) and Mobile Agent (MA). Ontologies are used as a main interconnection element for domain knowledge representation, agent-to-agent communication and most important for agent-to-business user communication. A very important element of an environment is the World Wide Web, where agents play information retrieval role for the purpose of decision making. The retrieved information is included in central knowledge base and available for further inclusion in Data Mining and Data Warehouse analyses. After all information from internal and external resources is gathered it is then furthermore considered by KDA, with the emphasis on inference over several task ontologies. The system needs to be context aware and consider the relevant features of the business, i.e. context information such as time, location, and user preferences (Liao, et al.

2005). An initial analysis has to be captured in the ontology by business users, while execution and optimisation is left to agents. When some action is required from business user, he is notified and has the ability to act or change the rules of agent's execution.

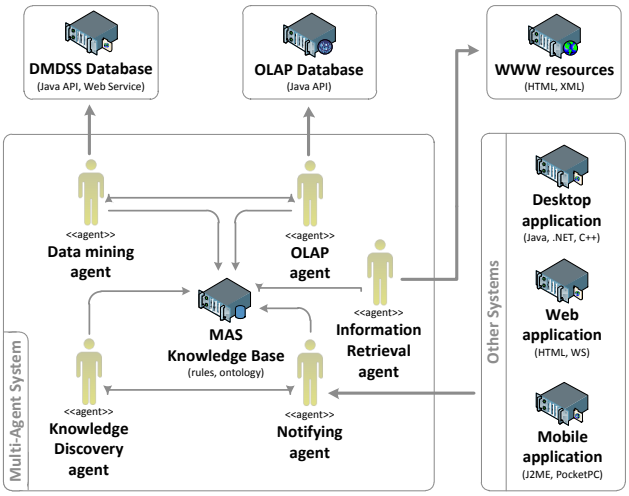

Figure 1: Architecture of MAS for Decision Support in Enterprises

To enable these functionalities we introduce ontologies as a mediation mechanism for knowledge exchange between actors (agents and business users) that cooperate in DSS-MAS. According to Guarino in (Guarino 1998) ontology can be structured into different sub-ontologies. Following similar guidelines we have defined upper ontology named Common ontology and combined domain and task ontologies in Notifying ontology, Information retrieval ontology, Data Mining and Warehousing ontology. Common ontology is limited to abstract concepts and it covers reusable dimensions, which are primarily used by KDA. Task ontologies specify concepts of notification, Information Retrieval and Data Mining and Warehousing. The ontology is not only a central repository for business vocabulary representation with all the restrictions and formal definition of business, but also consists of dynamic elements in a form of business rules that are used to support operation, advanced analyses and reuse of existing systems.

Our research uses domain of medium size construction company as a platform where we focus on the sales of construction services. Manipulation with internal data storage is handled by two types of agents – OLAP Agent (OLAPA) and Data Mining Agent (DMA). They both have distinct tasks but still share common goal – periodically or on demand autonomously executing analyses models. The information about the execution is stored in the ontology (based on business user preferences) or is requested by another agent in the system. OLAPA has on first hand very straightforward task of performing OLAP analyses on behalf of an agent or a business user and reporting its findings back to the requesting entity and all other entities that should be proactively informed, according to the business policy. Nevertheless OLAPA does much more – after each execution it prepares the report for business user based on detected findings.If certain finding is substantially different from previous running further analysis is performed to discover the reason of change by drilling down or up the hierarchies and levels.

By capturing the knowledge in ontology we enable business users to change the behaviour of agents by simply altering the ontology using simple graphical user interface. This interface incorporates all logical restrictions defined in ontology and does not allow users to enter false inputs and most important does not require technically educated users. It is believed that, for the

business intelligence of an enterprise, only about 20% of information can be extracted from formatted data stored in relational databases (Tseng and Chou 2006). The remaining 80% of information is hidden in unstructured or semi-structured documents. For that reason in DSS-MAS we introduce Information Retrieval Agent (IRA) for information retrieval of data mainly from the World Wide Web. The tasks that IRA performs can be grouped into three categories:

- Identification of new construction companies found online,
- analysis of other construction companies services and
- extending Data Warehouse with information found online.

Every new construction company found online is analysed. IRA traverses through construction companies and determines services with their market prices and stores this information into Information retrieval ontology to be available for further knowledge derivation by Knowledge Discovery Agent (KDA). Found services are used to determine new market trends, enable price comparison between competitors, facilitate possible inclusion in organisation's sales program etc.

One of the tasks that IRA also performs is extending Data Warehouse analyses with information found online. While business user performs OLAP analyses, he deals with only internal information about the business, but before decision making other resources also have to be examined, e.g. news about the suppliers and competitors, opinions about certain products and organisations etc. IRA therefore scans the dimension data (through hierarchies and levels) from Data Warehouse dimensional schema and uses this information to search several internet resources (news archives, forums, stock changes, Google trends etc.). When users review OLAP reports these data from the Internet is also displayed according to their restrictions in dimensions. Knowledge Discovery Agent (KDA) is very important element of DSS-MAS since it consolidates all findings from Information Retrieval, Data Mining and Warehousing and furthermore mediates derived findings to Notification. To fully employ inference capabilities over several ontologies the organisations' business rules are essential. While business concepts are captured in ontology, these concepts further have to be yet linked together. Generally business rules are prepared by business users and not by technical users and also business rules in enterprises tend to change frequently; therefore we introduced architecture (see Figure 3) for business rules management.

As depicted in Figure 1 Notifying Agent (NA) represents an interface to DSS-MAS for all external applications and business users. The main role of NA is the information dissemination by simply delivering the right information at the right time to the right users. All knowledge about notification is captured in Notifying ontology, where every user has his own context defined and the position within organisation across two dimensions – organisational unit (e.g. Marketing, Sales, Human resources etc.) and decision making level (e.g. CEO, CIO, CFO etc.). According to that position rules for delivery of several message types are defined. These message types range from Notification to Warning and Critical alert.

3 PROTOTYPE IMPLEMENTATION

The selected language for ontology presentation was OWL DL (Russomanno and Kothari 2004). Besides OWL logical restrictions, SWRL rules were also used due to its human readable syntax and support for business rules oriented approach to knowledge management. This approach enables storing schema, individuals and rules in a single component, which makes management much easier.

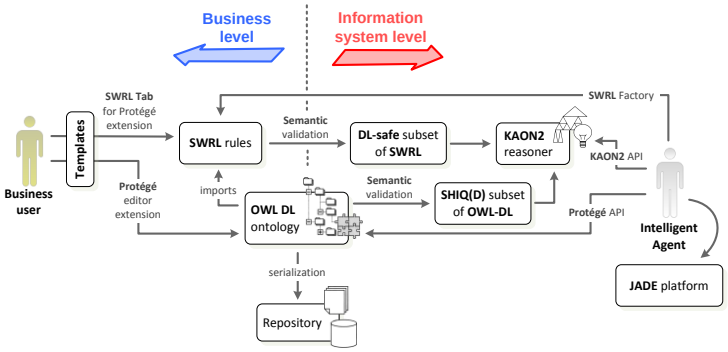

Figure 2: Prototype implementation architecture

The user interface for ontology manipulation for business users is based on Protégé editor and SWRL Tab for Protégé. It enables entering OWL individuals and SWRL rules where a step further is made towards using templates for entering information (see Figure 3). At the execution level KAON2 reasoner is used to enable inference capabilities. The rules and entities from ontologies are employed as knowledge representation mechanism in agents. We selected FIPA compliant Multi-Agent System platform JADE in DSS-MAS as it offers broad range of functionality and is most widely used platform. For Mobile Agent implementation an add-on JADE-LEAP was used to support the mobility of agents.

With the use of templates with ontology, business logic is excluded from the actual programming code whereas the majority of data for templates is acquired from restrictions and natural language descriptions in ontology, while others are prepared by users with technical knowledge. The main goal of using mediation with business rule templates is to enable acquiring knowledge from actual knowledge holders i.e. business users and enable transformation of this high-level knowledge to information system level, where this data can be directly used for inferencing purposes and bring added value without any further programming by technically educated users.

4 CLOUD

The proposed system is very complex and relies on large amount of data. Sometimes even OLAP processing takes rather a lot of processing power. So we decided to deploy our prototype in the cloud to see its performance and what is more important to show that the costs of the proposed ontology based agent system can be lowered if we use a cloud as an infrastructure. We compared performance and operational costs of our proposed prototype on physical computer (four CPUs, 8 Gb of RAM and 1 Tb disk space) with comparable virtual machine in the cloud.

We tested the performance of virtual machine and physical computer both running Windows Server 2008. For that reason we developed special test scenarios that measured execution times and responsiveness of each system. We found out that the test system on physical computer outperformed the one in the cloud by more than three times. That's not bad at all especially if we also consider the costs of using cloud.

Overall costs were constituted from the following main components: data transport, processing power and data storage. We tested our prototype on Windows virtual machine for one month (40 hours of CPU time). That was the estimated time for such system in real company. The highest expense of using virtual machine represented data storage (88$), then data transport to the cloud (66,75$) and finally processing power (46,4$). That's 201,15$ for all operational costs against

estimated operational costs for physical computer running Windows Server which were 2000$. We can see that overall costs are approximately ten times lower if we decide to use cloud computing.

5 CONCLUSION AND FUTURE WORK

In this paper we discussed Multi-Agent System for Decision Support in Enterprises (DSS-MAS) where internal and external data was integrated using agent-oriented approach and ontologies as a common interpretation basis for data and metadata. Agents were used due to their mentalistic notions for modelling, similarities between the agent in the MAS paradigm and the human actor in business organisations and also great possibilities for the use of ontologies as their knowledge base. The external information from the Web was integrated with the data in organisation's DW and after applying business rules new knowledge was derived by employing agents' inference capabilities. Tasks like information retrieval from competitors, creating and reviewing OLAP reports are autonomously performed by agents, while business users have control over their execution through knowledge base in ontology. The research also emphasized agent-to-business user communication and trying to minimize that gap. This was accomplished by introducing different views on ontologies for business user and agent. While agents dealt with formal description of business concepts, logical restrictions and rules, business user had simplified view on formal description of knowledge. User was able to manipulate with ontology through templates, where very little technical knowledge was required. The role of the mediation mechanism was then to translate these business level concepts into formal descriptions at information system level. Several use cases were introduced to show application in different scenarios, mainly focusing on virtualization aspect.

6 REFERENCES

Erdogmus, H. 2009. *Cloud Computing: Does Nirvana Hide behind the Nebula?* IEEE Software, March/April 2009

Kang, N. & HAN, S. 2003. *Agent-based e-marketplace system for more fair and efficient transaction*. Decision Support Systems, **34**, pp. 157-165.

Lei, Y., Motta, E. & Dominque, J. 2002. *IIPS: An Intelligent information presentation system*. In 7th International Conference on Intelligent User Interfaces, San Francisco, USA.

Liao, S. H., 2005. *Expert system methodologies and applications - a decade review from 1995 to 2004*. Expert Systems with Applications, **28**, pp. 93-103.

Russomannno, D. J. & Kothari, C. R. 2004. *Expressing inter-link constraints in OWL knowledge bases*. Expert Systems, **21**, pp. 217-228.

Tewari, G., Youll, J. & Maes, P. 2003. *Personalized location-based brokering using an agent-based intermediary architecture*. Decision Support Systems, **34**, pp. 127-137.

Tseng, F. S. C. & Chou, A. Y. H. 2006. *The concept of document warehousing for multi-dimensional modeling of textual-based business intelligence*. Decision Support Systems, **42**, pp. 727-744.