

Agent Oriented Approach for Integration of BI Systems

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Abstract. Decision Support in enterprises is gaining its importance in the age of Internet and e-business. While dealing with the need for fast response in the dynamic competitive environments and rapid increase of information available on various networks we propose Multi-Agent System approach to backend Decision Support. Research case study presented in the paper is from the domain of mobile communications with system's main goal of delivering right information at the right time to the right users. We integrate several BI systems such as Data Mining and Data Warehousing with information available on the Internet. Ontologies are used to store derived knowledge, to support knowledge exchange between our MAS and other systems, to support agent-to-agent communication and enable seamless extending of MAS capabilities.

Keywords. Intelligent agent, MAS, ontology, decision support.

1. Introduction

In order to run business effectively, an organisation needs intelligence about competitors, partners, customers, and also employees as well as intelligence about market conditions, future trends, government policies and much more. For example, let us consider competitor intelligence information in the domain of mobile communications. This information will include competitor's strategies, including marketing and sales policies, customer information, how to manage customers, and information about their partners. Then an organisation can analyse this information and determine whether to develop or launch a new product, how to attract new customers, and perhaps better manage existing customers.

There are several sophisticated products and technologies available on the market, such as Data Mining and Web Mining applications in Business Intelligence, Customer Relationship Management, special applications for marketing,

sales, finance etc. Organisations expect these applications to support analyzing competitor strategies, customer profiles, determining business strategies, building and analysing customer profiles, developing customer-specific products, carrying out targeted marketing, predicting sales trends etc.

Practitioners and academia have both noted the significant benefits that information systems integration within the enterprise can bring about for businesses in terms of reduced costs, improved product line in tune with market needs, and responsive and improved customer service [1, 2, 6, 8].

The purpose of this article is to present our research in the area of integrating several information resources for the objective of Decision Support using Multi-Agent approach, based on ontologies. Case study of a mobile operator was implemented in Java programming language using JADE and Jena frameworks for agent and ontology manipulation.

The rest of the paper is organized as follows: in section 2 we make a brief introduction to decision support with the emphasis on presenting our view why conventional approaches fail to satisfy growing needs of decision makers. Section 3 introduces our Multi-Agent based approach in integrative business information systems. A particular attention is given to notification of business users as one of the crucial part of effective decision support. At the end, the role of ontologies and conclusions for the future work are presented.

2. Decision support

Decision Support Systems (DSS) are tools that managers use to make effective decisions whereas decision support is a technology that overlaps with Data Mining, Data Warehousing, knowledge management, machine learning, statistics, and other technologies that help to manage an organisation's knowledge and data [5]. Decision support in the age of Internet and e-business is gaining its importance DSS was in

the past merely seen as a standalone approach whereas the need for closely linking DSS with business processes is still present and not resolved by new concepts, architectures or frameworks [1, 3, 4].

While integration of information systems in business environments provides some DSS functionality, there is a need for the development of decision support tools, which can be tightly integrated with the business environment. In [13] a comparison of DSS, expert systems and intelligent agents, depicted in table 1, has been made.

Table 1. Comparison of DSS, expert systems and intelligent agents

	Decision support	Artificial Intelligence
Traditional	DSS	Expert systems
Situated	Situated DSS	Intell. agents

We can summarize that expert systems are evolving into intelligent agent supported systems for decision support. The need for evolution lies in effective linking of DSS to their problem environments. Intelligent agents facilitate higher level decision making with automation that leads to improvement of strategic capabilities of organisations. Furthermore, nowadays we are witnessing an increased interest in real-time response of DSS, where agent paradigm perfectly fits in. Very important is availability of information irrespective of decisions maker location and that is special attention which we point out in our research.

3. Integrated Multi-Agent environment

Multi-Agent Systems (MAS) are gradually becoming a new paradigm for developing distributed computing systems. This paradigm provides an appropriate architecture for design and implementation of integrative business information systems. Agent-based technology supports complex information systems development by providing natural decomposition, abstraction, and flexibility of management for organizational structure changes [6].

The research on intelligent agents and multi-agent systems has been on the rise over the last two decades. The stream of research on business information systems, enterprise integration [7, 8,

9] makes the MAS paradigm a very appropriate platform for integrative decision support within business information systems. Similarities between the agent in the MAS paradigm and the human actor in business organisations in terms of their characteristics and coordination lead us to a conceptualisation where intelligent agents in MAS are used to represent actors in human organizations.

In our approach agents automate much of the work and enjoy limited authority in performing minor and routine tasks. Agents also collaborate with the decision makers when necessary. Our approach emphasizes the use of ontologies as central knowledge repository for our system and backbone for agent-to-agent communication. Furthermore we point out notification of business users as a very important part of our system.

3.1. Architecture

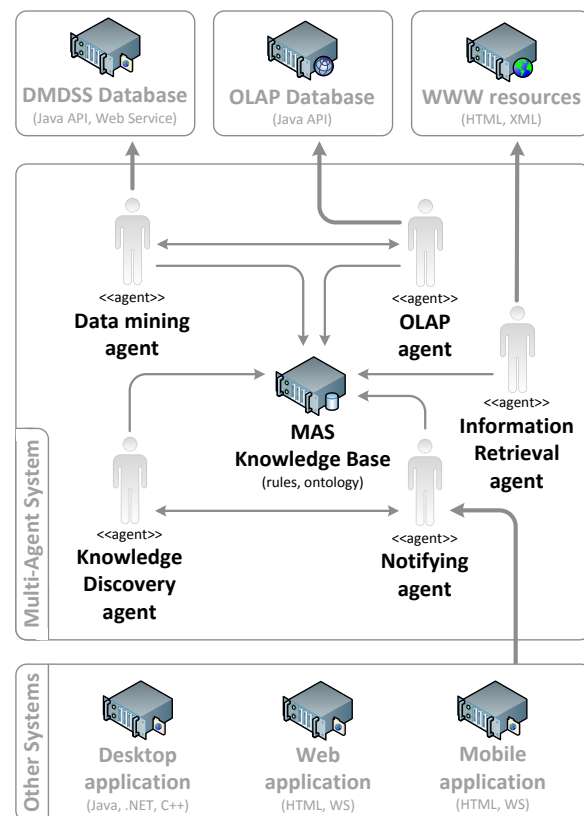


Figure 1. Extended Use-case diagram of MAS for Decision Support in Enterprises

Multi-Agent System for Decision Support in enterprises that we propose in this article is introduced on figure 1. Case study is from the domain of mobile communications and is based on business environment and information sources of one of the leading mobile operators in Slovenia. Our MAS uses different systems such

as Data Mining Decision Support System [10], OLAP System, various resources on the Internet etc.

Global goal that agents in our MAS strive to is supporting decision making process while using several existing systems for business analysis that already exist in organisation and employing information from environment where organisation resides. A very important element of an environment is 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.

Moreover the sub-goal of MAS is delivering the right information at the right time to the right users. Data Warehouse analysis could show that provider prices of specific product have risen last month, whereas Information Retrieval agent discovered that market prices of competitors dropped down last week. That could be a matter of importance for decision makers when negotiating with vendor and that's why business users should be alerted as soon as MAS discovers this fact and not only when they request the report.

3.2. The role of agents

In order to ensure that agents can work effectively in achieving overall system goals, various coordination techniques have been developed. Common coordination techniques include organisational structuring, meta-level information exchanging, multi-agent planning, contract net, negotiation etc. Organisational structuring gives general information about the structure of an agent community as a whole. We have organised agents in our MAS into sections depicted in figure 1 and the roles of agents are as follows: Data Mining agent, OLAP agent, Information Retrieval agent, Knowledge Discovery agent and Notifying agent.

Millions of people and thousands of applications are adding information to the internet/intranet on a daily basis. Rather than quickly accessing relevant information, time and productivity are lost in the search for information. Technologies are needed that semantically understand information requests so that precise information can be delivered quickly. The first step is to create a central vocabulary within an ontological context in order to standardize processing concepts. With

availability of Semantic Web technologies we have the tools required for this task in multi-agent environment. As described in detail in section 3.5 common ontology has been constructed for the purpose of MAS. We believe that finding knowledge on the Semantic Web can be done more intelligently than just looking up words in a dictionary, even if word look-up is based on OWL. In addition to ontology backend services (e.g. WordNet), inference engines can provide a new dimension of reasoning capabilities. That's the reason why MAS Knowledge Base (see figure 1) is seen as central location of knowledge from all collaborating parties (external systems, resources in the environment etc.). Every agent from Data mining area, OLAP area, Information Retrieval area and Notifying area, uses and when needed, updates concepts, rules and individuals in common ontology.

Information Retrieval agent plays an important role in handling information dissemination. Among tasks such as filtering and transforming information into our knowledge base it also performs more advanced actions like identifying new sources of information (e.g. new online shops that sell mobile phones and accessories). It constantly monitors market and in case of any important news informs Notifying agent that handles notifying business users.

Entity responsible for derivation of new knowledge from existing information is Knowledge Discovery agent. It represents important part in coordination chain of our MAS for decision support in modern organisations. Main goal that is trying to achieve is consolidation of information from all parts of the system – Data Warehouse, Data Mining, various internet resources information and user notification. Semantically understanding and standardising processing concepts of results from multiple domains is achieved using central vocabulary in form of common ontology (section 3.5). Knowledge base is constantly being updated and therefore determining the way other agents in the system exploit information sources. For example if new phone is discovered on the competitors market this is immediately used in Data Mining forecasts.

3.3. Data Warehouse and Data Mining

The way transactional databases are optimized makes the data difficult to exploit by managers and analysts who need aggregated and

summarized information. New types of systems have been developed since transactional systems are not designed to support the decision processes. These systems usually have Data Warehouse as a central component and are optimized to simplify complex analyses. Data warehouse assembles the data from various heterogeneous databases. While data warehousing organizes and formats the data to support management functions, data mining attempts to extract useful information and predicts trends from the data. Data Mining techniques, like statistical reasoning, neural networks and various other artificial intelligence techniques, have been around for decades. Thuraisingham et al. in [13] have come to conclusion that the main reason for data mining becoming so popular is that now we have data to mine.

The question is: "How we can incorporate data mining into data warehousing for decision support purpose?". There is a small difference between those concepts, because warehouses have built-in decision support capabilities and some warehouses even carry out predictions and trends. Therefore in some cases, warehouses carry out some of the data mining functions. In general, in the case of warehouse, the answer is in the database. If business analyst wants to know answer to question: "How many Nokia phones have been sold in August 2005?" we can ascertain that the answer is in the database. However, the answer to a question: "How many Nokia phones do you think we will sell in March 2006?" may not be in the database. Based on selling patterns of the organisation, we could predict the answer to this question using data mining.

In our MAS two types of agents for business analyses exist – Data Mining agent and OLAP agent. OLAP agent uses Data Warehouse and analyses cubes by different dimensions and hierarchies as presented in Data Mining and Warehouse ontology. Ontology also specifies thresholds when some actions are required. That could include sending a message to Notifying agent which informs all users that need to be notified about the event that occurred. OLAP agent also drills down the Data Warehouse to locate the source of exceeding threshold value by adding constraints in analysing sub dimensions and hierarchies. Whereas OLAP agent tries to answer questions about the past, Data Mining agent in our case works with predictions in the future. The process that Data mining agent

carries out, uses information consolidated from Data Warehouse and other resources on the internet. Several models are built and compared to find differences through timeline. In case of major differences Notifying agent is informed to pass on the alert to concerning users. OLAP agent and Data Mining agent are also quite interlaced. When there are some anomalies detected in data warehouse this indicates a signal for Data Mining agent in model creation phase in sense of modifying rules in common ontology. Collaboration vice versa is achieved with difference in data mining models that requires analysis in data warehouse with smaller grain.

One use case is determining "bad customers" i.e. those who are considering leaving to a competitive mobile operator. Using information from Information Retrieval agent that searches for online shops selling mobile phones and accessories and then analysing market behaviour would result in cluster of phones, potentially interesting for customers that are likely to leave and go to the competition. Those phones could then be offered at lower prices and consequently try to keep unsatisfied customer, which is important in small and filled to capacity markets where there are only a few new customers left.

3.4. Notification of business users

Delivering new and relevant information is an important task in all phases of decision making. In a trivial case, the relevant information is imported into DSS from environment. More advanced cases require locating, filtering, transforming relevant information and generating alerts. In our approach we propose a set of notifying agents, which play role of accessing, filtering, converting and monitoring of information and generating alerts when a critical situation arises. We also introduce more advanced features like identifying new sources of information (e.g. using search engines or manually crawling the web).

The ideal goal is to get the right information at the right time to the right users. This could be achieved either through the push model, where information is pushed to the user, or a pull model, where the data is requested, or a combination of push and pull. In our MAS that we introduce, Notifying agents play an important role in information dissemination. The information is retrieved by Information retrieval agent either by monitoring or when requested. Monitoring agent can monitor for information

production and then this information is retrieved and filtered and later given to the user (information consumer). This is referred to as push model of retrieving information. To support wide range of information consumers we have implemented several source types, such as RSS (Really Simple Syndication), Windows Alerts, E-mail, SMS etc.

Next model of retrieving information is called pull model. In this case the consumer requests information and Locator agent finds the information source and informs Information retrieval agent to retrieve the information.

The challenge of notifying business users is to get the information to the user without overloading him. Because this is very demanding, we cannot expect that this problem will be solved completely. Using context for users has proven as a very useful approach [11], because notifying process is adapted for each user independently, resulting in better and up to date information that user needs.

3.5. The role of ontologies

Ontologies are very useful whenever two or more actors have to work together. They are very important for collaboration, agent-to-agent communication, knowledge management and for interoperability reasons between different database systems. One of the most adopted definitions of ontology is that ontology is a specification of concepts to be used for expressing knowledge [12]. That includes entities, attributes, relationships and constraints.

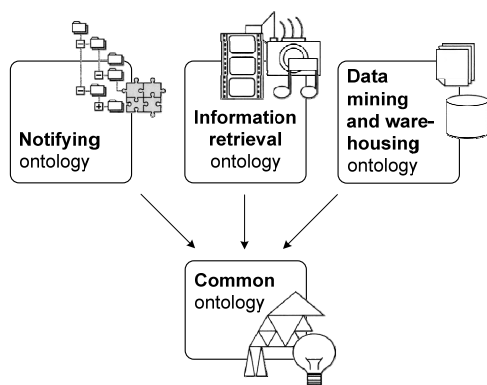


Figure 2. Developing common ontology from multiple domain-specific ontologies

Even though the Semantic Web was created to represent document content, it makes sense to apply this concept to other areas where a common language and carefully designed definitions are necessary in form of common ontologies. In our approach we composed 3

domain ontologies that are based on organisational structuring and are as follows: Notifying ontology, Information Retrieval ontology, and Data Mining and Warehousing ontology. In Data Warehouse area, definitions for figures, dimensions, cubes, reports and their attributes (e.g. data field of the legacy system) are captured in ontology. OLAP agent then, in the name of business user, analyses cubes and in case of major changes drills down to trace reason for deviation.

Information Retrieval ontology mainly deals with World Wide Web concepts and retrieval of information located on web sites. It is concerned with structured and semi structured sources of information and rules for extracting, cleaning and storing of information into knowledge base.

The purpose of Notifying ontology is to develop architecture for relevant information location and transformation and also generating alerts for business users. Elements of context are also presented for defining users needs and requests so that right information can reach the right user at the right time.

The elements of common ontology, derived from domain ontologies were also efficiently used in agent-to-agent communication. This modular approach results in very little effort in adding new agents to MAS and straightforward way of extending capabilities. Using ontologies for knowledge modelling gives an organisation opportunity to separate domain knowledge from single software applications. In doing this, independence is achieved, so that the data can be used as the knowledge basis in other applications within or outside MAS.

4. Conclusions and future work

The Multi-Agent Systems paradigm provides and excellent architecture, technological platform, and modelling approach for developing and implementing systems that are flexible and can easily and quickly grow and adapt to changing business environments.

Negroponte predicted that “Future human-computer interface will be rooted in delegation, not the vernacular or direct manipulation”. These interfaces populated with personal digital assistants and virtual secretaries will be able to perform certain tasks, including scheduling, filtering information, learning user preferences, and many others in an (semi-) autonomous fashion. We follow this inspiration in designing Multi-Agent System for Decision Support in

Enterprises whereas we do not want to be too optimistic, however Semantic Web technologies have evolved during last few years to a level that enables implementation of majority of ideas from Negroponte.

Case study of mobile operator has been presented for integrative decision support within business information systems. During development lifecycle agent oriented methodologies and AgentLink MAS meta-model have been used. Future work includes completing implementation and testing phase, continually improving design of ontology, adding new information sources to MAS and increase number of interfaces to our systems through Notification agent. Furthermore we will also emphasize our work on stronger integration of OLAP and Data Mining agent. One of the issues we are working on is tracing down all variations in data warehouse by OLAP agent. Data Mining agent then considers this information in building and analysing new models for prediction of future trends.

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