SEMANTIC INTEROPERABILITY
Information Integration by using Ontology Mapping in Industrial Environment

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Abstract: Interoperability requires two components technical and information integration. Most of the enterprises have solved the problem of technical integration but at the moment they are struggling with information integration. The challenge in information integration is to preserve the meaning of information in different context. Semantic technologies can provide means for information integration by representing the meaning of information. This paper introduces how to use semantics by developing ontology models based on enterprise information. Different ontology models from diverse sources and applications can be mapped together in order to provide integrated view for different information sources. The domain area of this case study is heavy industrial environment with multiple applications and data sources.

1 INTRODUCTION

Today business processes must be managed and modified more effective than ever before. Processes need to adapt to consolidation, mergers and acquisitions, joint ventures, divestitures, regulatory compliance issues, shifts in business models, changing customer expectations, industry standardization and business process outsourcing (Smith and Fingar, 2002). Successful management of a company requires overall management of all processes and information connected to them. All changes in business processes have influence on several information systems in enterprises and therefore seamless communication and integration of data and information as well as synchronization of inter-organizational business processes are complex problems (Li et al., 2006). Enterprises are using huge amounts of time and money to solve interoperability problems of software systems. At the moment enterprises are using 30 to 40 % of their IT budget for integration problem (Gartner) and the average time spent for integration of single interface is 2 PM. The most worrying thing is that some enterprises spend up to 80 % of their IT budget for updating their legacy systems to integration and extensions (Polikoff and Allemang, 2003). As the enterprise collaboration is increasing al the time and requiring more and more integration, the costs of inadequate interoperability will be unsustainable.

Interoperability is comprised of both technical integration and information integration. Most of the current solutions are focused only on technical integration, to link disparate software systems to become part of a larger system while information integration is focused on preserving the semantics while transforming the context (Pollock, 2001). Yet any moderately complex integration work requires both types of integration. There is two strategies for migrate system integration problem with the enterprise: the development of an *enterprise message model* as a reference point for flexible and economic integration and the use of a *semantic broker* so that each application would not have to understand the semantics of every other application (McComb, 2004). Today, enterprises are using the message model as a technical integration solution although the architecture still has many unsolved problems like laborious configuration and differences in the information interpretation between designers. Examples of such technical solutions that use common transportation layer for integration are

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IBM WebSphere, Microsoft Messaging Queuing and BEA ESB.

Information integration is based on semantic interoperability that emphasizes the importance of the information and focuses on enabling content, data, and information to interoperate with software systems outside their origin (Pollock and Hodgson, 2004). The aim of semantic interoperability is to provide the ability to bridge semantic conflicts arising from differences in implicit meanings, perspectives, and assumptions for co-operating enterprises, thus creating a semantically compatible information environment based on the agreed concepts between different business entities (Park and Ram, 2004). The basis for ontology-driven knowledge management was formed in EU projects On-To-Knowledge (On-To-Knowledge, 2008) and continued in Semantic Knowledge Technologies (SEKT) (SEKT, 2008) that researched the development and exploitation of semantic knowledge technologies.

This paper proposes the use of semantics for solving the interoperability problems above technical integration. The presented work is conducted in Sebi-project (Sebi, 2008) that concentrates on solving interoperability problems in industrial environment by using semantic technologies and especially ontology-based knowledge management. This paper presents the architectural approach of using semantic technologies in Sebi project. The presented approach is tested in a case study of integrating information from various sources in industrial production environment. This paper gives a brief introduction to the objectives of the case study and overviews the basic elements of the development process.

2 CASE STUDY OF INFORMATION INTEGRATION

Interoperability between systems can be supported with semantic technologies by developing a shared information model for the use of different solutions. This model provides an integrated view for heterogeneous data sources within a company. Integrated view can be composed several ways according to the requirements. It can support business process management (BPM) or different task-specific purposes within BPM like controlling the delivery reliability or lead time. Semantic models can also be used in enterprise collaboration. Using semantically enriched data different parties having divergence in ontologies are able to communicate with each other; communication can involve applications, information systems, processes, companies in value-chain and humans.

The semantic interoperability research has categorized three broad research areas: *mapping-based, intermediary-based, and query-oriented approaches* (Park and Ram, 2004). Mapping-based approach attempts to construct mappings between semantically related information sources while the intermediary-based approach may also rely on mapping knowledge established between a common ontology and local schemas. Query-oriented approach is focused on interoperable languages which can be used for formulating queries over several databases. Semantic architecture methodologies are divided into three groups: one-to-one mapping, single shared ontology and ontology clustering (Alexiev *et al.*, 2005). The methodologies have different approaches of using global and local ontologies, one-to-one paradigm uses local ontologies alone, single-shared ontology use global ontology without local ontology and mix of single-shared and one-to-one mapping uses global ontology with local ontologies (Bruijn and Feier, 2005).

According to Sebi view the interoperability can be best achieved by combining all three different approaches of interoperability: mapping-based, intermediary-based and query-oriented. In this case study we have used mixed paradigm with one global and several local ontologies. The interoperability architecture is presented in Figure 1.

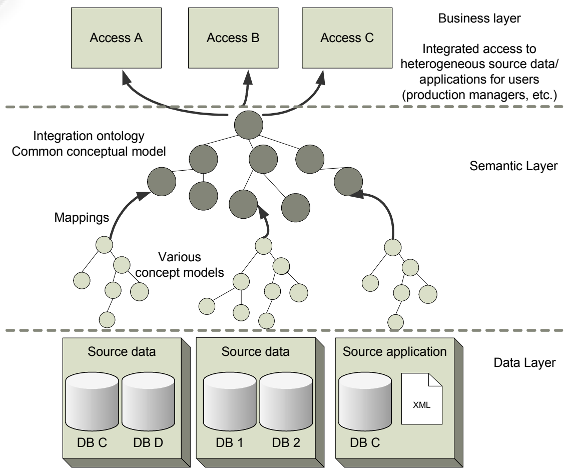

Figure 1: Sebi interoperability architecture.

In data layer is the source data from heterogeneous data sources and applications. The source data is derived from various databases or other electronic sources (eg. XML-files, ontology files). *Semantic layer* represents the concept models of domain information derived from various data sources. Integration ontology is a common conceptual model that defines key concepts of the domain with related relations and attributes. Integration ontology is developed with ontology building tool in collaboration with domain experts. The mappings between concept models and integration ontology are defined with the same tool in order to connect the source concept models to integration ontology. *Business layer* offers different views for integrated information according to user's need. The information is requested by executing queries into integration ontology by using middleware tool. Run-time implementation of queries enables real-time access to distributed information and supports for example decision making in company management.

The case study describes the process of developing interoperability for industrial environment and the case enterprise operates in the domain area of heavy manufacturing. The aim of the case was to integrate the information used in manufacturing process control. The enterprise has several information systems (ISs) for controlling manufacturing process; each IS having a totally different concept hierarchy, database structures and information models. This posed constant problems for information management and furthermore caused extra costs and loss of resources. The case involved three ISs, one containing failure and breakdown information, another IS controlling machines and devices and the third IS needed the information from the previous two. The operating environment of the case is presented in Figure 2.

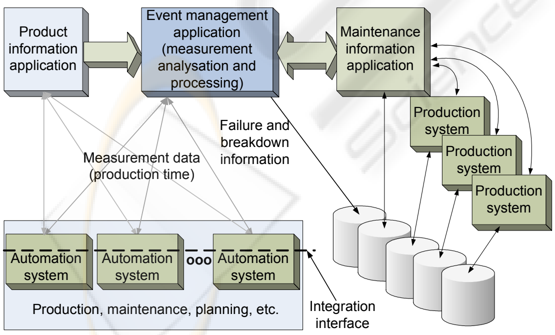

Figure 2: Operating environment of the case.

The objective was to integrate ISs together in order to offer a single view into machine, device, breakdown, and failure information to enable proactive maintenance in manufacturing process, planning of maintenance work and controlling the lead time of maintenance. The main requirements for the solution were to enable frictionless information sharing, flexibility of the integration and effective maintenance of the integration.

The technical integration of the case was solved by using a message broker that transmits information between ISs, databases and different data sources. In the semantic solution source ontologies from different databases are modeled using ontology engineering tool. In this case OntoStudio (Ontoprise, 2008) tool was used for developing automatically source ontologies, designing integration ontology, defining mappings between source ontologies and integration ontology and creating intelligent reasoning. The development of integration ontology was also developed by OntoStudio. It was a very demanding phase and it was done in collaboration with experts from the domain area. The integration defines shared semantics of the data and contains all the important concepts with related attributes and restrictions from the domain area.

The connections between source ontologies and integration ontology were realized using mappings and rules. When using mappings, the concept from source ontology is connected to the suitable concept in integration ontology. In complex cases, where the concepts are not correspondent, the mappings can be made by using reasoning. The reasoning may be based on similarity of concepts and the meaning of concepts. In this case the rules were created using F-logic (Kifer *et al.*, 1995) as an inferencing language. Reasoning enables upper level mappings, where rules deliver information to a corresponding place at the lower level. This makes the maintaining of mappings easy, because changes in upper level cause changes in the whole concept tree. By using rules the amount of mappings can be reduced and it is easier to piece mappings together. Figure 3 describes a rule that get inputs from source and types all failures which "FailureType_id" is one to mechanical failure to the business ontology.

Integration ontology operates as a link between different ISs by offering access to the information. The information is queried through integration ontology which provides access to information in databases through source ontologies. The queries are executed to the integration ontology using a middleware tool.

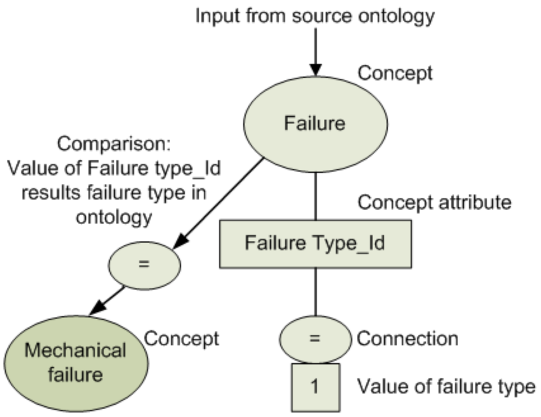

Figure 3: Rule for reasoning the type of the failure.

3 CONCLUSIONS

System interoperability is complex problem which has become unbearable for enterprises in dynamic environment. Constant integration work consumes time and money that enterprises could otherwise use for development of new systems. System integration and the maintenance of existing point-to-point integration solutions are consuming lion's share of the companies' IT budget. By using semantics the prerequisites to solve the interoperability problem is significantly increasing.

This paper presents our approach of semantic solution. During the research different architectures, methodologies and tools for semantic interoperability were examined and the most suitable alternatives where chosen. Chosen ontology architecture allows flexible adaptation to the changes which take place in system combination. The interoperability between systems is implemented through integration ontology. The information from existing systems is modelled isto concept models that are mapped to integration ontology. Integration ontology offers real-time access to information in integrated systems for users and systems. It also offers effective tool for human-to-human communication. The functionality of the semantic solution was examined in case for manufacturing system interoperability.

The development of semantic solution is still on its early stage. The development requires new working methods, because new technologies require different approaches and the old working methods are not necessarily suitable. The research will continue by defining the time and costs of ontology development. Also the technical side of the solution and rule creation process still needs development. During the research it was realized that the wide adoption of semantics is still in future. Considerable amount of research has been done in the area of semantic interoperability, but real implementations, especially in industry, are few. The adoption of semantic technologies requires hard evidence of the functionality in real-life cases and quicker implementation pace. Whole process need to be handled, mere technical solution is not enough.

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