COLLABORATION ACROSS THE ENTERPRISE
An Ontology-based Approach for Enterprise Interoperability

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Abstract: In the current competitive industrial context, enterprises must react swiftly to market changes. In order to face this problem, enterprises must increase their collaborative activities. This implies at one hand high communication between their information systems and at the other hand the compatibility of their practices. An important amount of work must be performed towards proper practices of standardization and harmonization. This is the concept of Interoperability. Interoperability of enterprises is a strategic issue, caused as well as enabled by the continuously growing ability of integration of new legacy and evolving systems, in particular in the context of networked organisations. of the reconciliation of the communicated business semantics is crucial to success. For this, non-disruptive re-use of existing business data stored in "legacy" production information systems is an evident prerequisite. In addition the integration of a methodology as well as the scalability of any proposed semantic technological solution are equally evident prerequisites. Yet on all accounts current semantic technologies as researched and developed for the so-called Semantic Web may be found lacking. In this paper we present a methodology, which has resulted in the implementation of a highly customizable collaborative environment focussed to support ontology-based enterprise interoperability. The main benefit of this environment is its ability to integrate with legacy systems, rescuing enterprises from having to adapt or upgrade their existing systems in order to interoperate with their partners.

1 INTRODUCTION

Collaboration and knowledge sharing have become crucial to enterprise success in the knowledge-intensive European Community and the globalised market world-wide. In this market the trend in innovation of products and services is shifting from mere production excellence to intensive, collaborative and meaningful *interoperability* (De Leenheer and Meersman, 2007).

The main objective of this paper is to illustrate the features and the underpinning technology of a collaboration platform designed to support the effective interoperability within and between very large enterprises. A main key issue that this platform addresses is the variety and number of different resources that concur to achieve a cross-enterprise business service. A second key issue it addresses is the diversity of agreed (e.g. meaning negotiation when creating online contracts) models, and the

difficulty in adapting its integrated features and services to different situations.

These problems are addressed with a flexible solution, avoiding rigidity that occurs in the implementation and maintenance of existing cooperation platforms and their integration with an advanced semantic repository.

The proposed platform operates at two levels: at the front end, it enables the end users to access seamless collaborative (e.g., synchronous, asynchronous and semi-synchronous) as well as individual mode tools and services to extract valuable information; at the back end, it uses a sophisticated ontology framework to support and record the collaborative work, enhancing interoperability among different enterprises and other service providers.

The final part of the paper presents appropriate evidence regarding the usability as well as the functionality of the platform through a realistic case study.

2 ENTERPRISE INTEROPERABILITY

In general, interoperability is defined as *the ability of two or more systems or components to exchange information and to use the information that has been exchanged* (Athena, 2004, Interop, 2003). The European Commision (EC, 2006) adopts a broader notion with Enterprise Interoperability (note the capitals), which indicates *the field of activity aimed at improving the manner in which enterprises interoperate by means of ICT.*

Enterprise interoperability is considered "valid" if inter-business interactions are enabled at three main enterprise IT levels: *data*, *application* and *business* process (IDEAS, 2003). Figure 1 illustrates these levels, and how ontologies, being formal computer-based of concepts and vocabulary of the business context under discussion, are instrumental in these interactions as they provide the necessary shared semantic resources (De Leenheer and Meersman, 2007).
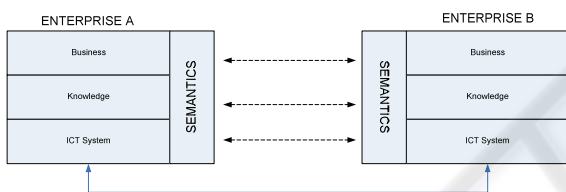

Figure 1: IDEAS Interoperability framework (adapted from IDEAS, 2003)

Data integration is not a novel issue, however an important share of so-called *legacy data* is crucial for competency is still locked in different corners of the enterprise.

Legacy systems are in many cases mission-critical. Large investments have been made in those systems, and it is clear that enterprises are very reluctant towards simply replacing those systems by newer equivalents. Especially in the case that the legacy system is consistent in its information processing, reliable in its operation, and predictable in its output.

A current trend in information systems is the adoption of Service Oriented Architecture (SOA). According to the OASIS Committee on SOA, a SOA is defined as *"a paradigm for organizing and utilizing distributed **capabilities** that may be under the control of different ownership domains"* (OASIS, 2006). In SOA, everything is a service, and services can be consumed by different systems. The benefit here is that any legacy system can be subdivided in several specific services, which can then be encapsulated in modern technologies and incorporated in a SOA architecture.

As such, a lot of the technical details (e.g., technology, format, syntax) are currently being taken care of. An important aspect here, which has not received enough attention in our opinion, is the need for decent information architecture. It is exactly here that proper semantics can be covered, and that the last frontier in computing (Meersman, 2002) can be tackled. Semantically unlocking the data in legacy systems, and deploying it across the boundaries of the enterprise, is a collaborative effort and requires a methodological approach.

Brodie and Stonebraker (1995) define a legacy information system as *"any information system that significantly resists modification and evolution"*. The technical annex of the Enterprise Interoperability roadmap by the EC (EC, 2006) simply states, *"Previous generation(s) of technologies,* [are] *now termed 'legacy'"*. In any sense, these type of systems are in many cases mission critical, and their failure can have a serious impact on business (Bennett, 1995). Next to pure technical issues such as hardware and interfaces, we can also add proper understanding of the concepts contained in and used by these systems (Bisbal et al., 1999).

Collaborative environments can be described as systems aimed at improving the experience of distributed users. Since distance between co-workers usually equates to less effective teams and inadequate project outcomes, the use of technology focussed to bridge this gap is considered to be essential (Tomek et al., 2003). By providing more effective communication tools, we enable distributed co-workers to collaborate, co-ordinate and communicate effectively on projects while distributed.

2.1 Issues

The majority of the researchers support the view that Enterprise Interoperability must come along with considerable performance penalty (Hauguel and Viardot, 2001, IDEAS, 2003). Thus almost all of the proposed models of frameworks used to evaluate the difficulties in Enterprise Interoperability focussing on communication, security and performance excluding the integration of a methodology focussed to serve the specific cause and integration and support for legacy systems.

Casola et al. (2007) argue that that although a service provider is able to guarantee a predefined service level and a certain security level, the mere

nature of interoperability and the utilisation of up to date technologies does not allow for automatic measurement of such attributes.

De Leenheer and Christiaens (2007) conceive the interoperability issue as a gap between different the social (communication between humans) and the technical (communication between machines) parts of any knowledge-sharing system. They adopt the four knowledge conversion modes described by Nonaka and Takeuchi (1995) socialisation (person to person), externalisation (person to machine), combination (machine to machine) and internalisation (machine to person).

2.2 The Need for a Methodology

According to the ISO standard, Enterprise Methodology (EM) is defined as the act of developing an enterprise model which is a representation of what an enterprise intends to accomplish and how it operates (Curtis, 1988). More precisely, EM is the representation of the structure, the behaviour and the organization of the enterprise according to different points of views (Casola et al., 2007):

- Functional, Informational, Physical (Business), Decisional, Processes and,
- Technical, Economical, Social, Human

With two interconnected visions:

- Global System Theory: the global view of the enterprise which collects objectives, structure, functions, evolution of the enterprise (dynamic), links with legacy systems and features of the environment;
- Local: detailed description according to the concepts of activities and processes.

The role of the methodology is to represent, understand and analyze through an enterprise model, the running of an enterprise in order to improve its performances (Curtis, 1988). The role of EM in Interoperability is to define interoperability requirements and to support a solution implementation. This contributes to the resolution of interoperability problems by increasing the shared understanding of the enterprise structure and behaviour. Several problems are related to interoperability and the absence of a concrete methodology to support it.

- The enterprise systems of the partners are not exchangeable (e.g., built using two different languages) or there are compatibility issues due to legacy support failure.

- The same term used by two systems does not mean the same thing (lexical ambiguity).
- Models of both enterprises show differences in practices, which are not aligned (output data of the first is semantically different to input data of the second).
- Models of both information technology (IT) systems shows incompatibility in information exchange.

Based on the above issues it is almost certain that the implementation of a concrete methodology will play a significant role in interoperability, particularly in terms of analysis to target the problems, which can appear in an approach of implementation of Interoperability and how to solve these problems. Interoperability problems are either related to (i) the semantics and vocabulary used to annotate the resources; (ii) the architecture and platform; and (iii) the model of the enterprise.

The first allows having a common language; the second allows the interoperability by the technical aspects (e.g., software, hardware, net) and the third models the supply chain to allow having interoperable practices at the interfaces. To solve the problems related to ontology, we have two options: either we set up a common and global ontology in all enterprises of the supply chain but the implementation and management will be difficult and tiresome, or we set up a common ontology only at the boundaries of the enterprises. Therefore, to bring an answer to some of the enterprise interoperability problems, we need to develop a methodology, which has the following functionalities:

- To manage the evolution of enterprise with the definition of different steps;
- To manage the performance of the supply chain in its entirety. The notion of performance is very important because it allows to bring the activity and to share the information, to promote the cooperation between the function in the enterprises and between the members of the supply chain, and the will to increase the vision angle inside the supply chain;
- To model only the information, the flows and the services which, concern interoperability of the supply chain. We don't speak about boundaries of an enterprise toward another enterprise but we speak about boundaries of the supply chain. Indeed, two enterprises don't need to be completely interoperable, but they need to be interoperable at the interface. For this reason, we have to define a supply chain boundary to separate the services which collaborate from the others;

- To take into account the human aspect i.e. the communication between different people and the human psychological aspects in the evolution of their enterprise. Indeed, in the evolution management, people are often recalcitrant to change due to the conflicts involved with their current legacy systems.

2.3 Role of Collaboration in EI

Collaboration is a key factor to success in any enterprise setting, and even more so when enterprise borders have to be crossed (e.g., interoperability in the extended enterprise). According to the FRISCO report (Falkenberg et al., 1996), a community constitutes a social system, where action and discourse is performed within more or less well-established goals, norms and behaviour. If collaboration within an (inter-) organisational community is to be successful, it is clear that proper communication should be in place, and that the semantics of the concepts being communicated are clear and agreed upon. Engineers or architects tasked with tying systems together need to understand each other properly in order to get maximum results out of their collaboration. Given the wide variety of design abstractions and differing terminologies, it is clear that communication in this kind of collaboration can lead to frustrating misunderstanding and ambiguities.

2.4 Levels of the Environment

The general architecture of the prototype is organised into the following four layers (Liapis, 2007):
- Configuration level
- Reuse level
- Reflection level

2.4.1 Configuration Level

The main metaphor of the environment is the concept of customizability. It allows the user to customise the tools according to the needs of the project by simply dragging and dropping them into the categorized tabs as illustrated in figure 3 (Liapis, 2007).

2.4.2 Reuse Level

Generally, the ability to reuse heavily relies on the ability to build larger systems from smaller ones, and being able to identify and resolve common

problems and conflicts between current and legacy systems (Malins et al., 2006). Reusability is often a required characteristic of collaborative environments (Liapis, 2007). The concept behind the implementation of this prototype was to provide users with appropriate tools in order to help them reflect on their ideas. The tools were implemented and arranged in a way that a user is constantly reminded of the next step, related sources, and about past and present approaches. The prototype is designed in a way that allows participants to work collaboratively, as well as individually, simultaneously following a loosely coupled group approach. All the contributions are being monitored and recorded by appropriate mechanisms providing meta-information as to the date and time the contribution took place, and the name(s) of the contributor(s).

2.5 Front-end of the Prototype

The following section presents the most significant features of the proposed prototype focussing on their architecture and contribution on the particular context.

Figure 3: Customisation of the main interface (adapted from Liapis, 2007).

2.5.1 Brainstorming

The proposed prototype includes the following two brainstorming techniques:
- Brainstorming
- Mind-mapping

Brainstorming, is a highly successful method, but requires significant support to be successfully used in a virtual setting (Diehl, 1987). There are two essential stages to any brainstorming process: the first being to generate as many ideas as possible (Malins et al., 2006); the second being to categorize or evaluate the ideas that have been generated (Liapis, 2007). The other technique is mind-mapping. Brainstorming through mind-maps may assist the design process by allowing the structuring of abstract concepts as well as concrete ones (Buzan, 2005). Both tools are using a series of data mining algorithms to allow users access to relevant third

party online resources while brainstorming. In addition the post it notes tool includes an integrated Really Simple Syndication (RSS) reader dedicated to scan the web for the latest technologies, approaches and events based on user input.

2.5.2 Collaborative Tools

Collaborative environments allow a virtual team or an organisation to share their work, seeing what others are doing, commenting and working together. Current collaborative technology still fails to support real life collaboration (Malins and Liapis, 2007). This problem is a direct result of not looking at the dynamic aspects of work. In collaborative technology that is able to support real-life interaction processes we need to pay attention to the fact that real-life situations are dynamic and involve complex tasks (Malins et al., 2006). Throughout the design process, the team needs to be able to communicate effectively. This is especially the case in an enterprise level where there is a tendency for a lack of communication because of the constant competition and the issues illustrated in the above sections. We have integrated two synchronous and one asynchronous collaborative service:

- Voice over internet protocol (VoIP) via Skype communicator
- Remote access via virtual network computing (VNC)
- Ontology server (DOGMA)

2.5.2.1 Ontology Management

Supporting an online team requires an advanced ontology management system, capable of mediating and sharing the contributions of the team. For a comprehensive state of the art on theories, methods, and tools for ontology management, see Hepp et al. (2008).
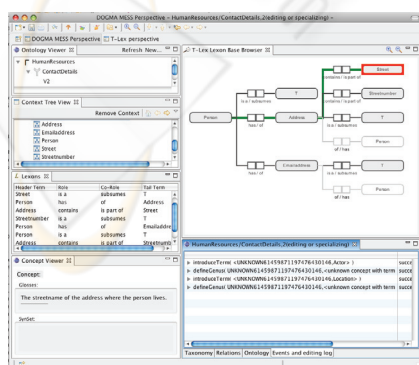

Figure 4: DOGMA Studio Workbench - the modelling tool.

The tool illustrated in figure 4 is the DOGMA Studio Workbench, which allows users to elicit and apply different ontological elements. They can browse and edit their ontologies, keep a record of different versions and share selected elements with other partners.

2.5.2.2 Recording Mechanisms

When a team collaborates using a groupware system its members must be co-ordinated in order to avoid possible conflicts (Malins et al., 2006). To preserve the integrity of the project throughout its complete lifecycle appropriate recording mechanisms should be integrated into the system (Liapis, 2007). Recording mechanisms allow participants to coordinate their work without communicating with others. This is an important characteristic as it prevents coordination breakdowns which frequently occur during collaborative design (Malins et al., 2006). The prototype consists of four different recording mechanisms to provide participants with a verification mechanism with regards to the evolution and security of the project. In addition participants can use the outputs as a reference for future work or to review the process (Liapis, 2007):

1. Video and audio recording mechanism for synchronous collaborative sessions
2. Automatic logging of users activity when using the environment
3. Automatic file versioning
4. Collaborative history mechanism in the modelling tool

The outputs of these files are being saved in the file repository tool with appropriate Meta information such as date, time, and participants.

2.6 Back-end of the Prototype

As the backbone of our knowledge management system, we adopted the DOGMA (Developing Ontology-Grounded Methods and Applications) framework for ontology engineering. A DOGMA inspired ontology is decomposed into a lexon base and a layer of ontological commitments (Meersman, 1999, 2001). A full formalisation of DOGMA can be found in De Leenheer et al. (2007), and an overview is given by Jarrar and Meersman (2007).

2.6.1 Concept Definition Service

Each (context, term)-pair then lexically identi es a unique concept. The concept is described by a gloss (short natural language description) and a set of

synonyms. Together with the linguistic representation in the form of the lexons, DOGMA remains close to natural language, which is indispensable in communication between collaborating teams.

2.6.2 Ontological Commitment

Any application-dependent interpretation of a set of lexons is moved to a separate layer, called the commitment layer. This layer serves as a mediator between the plausible fact types (lexons) and their axomatisation in applications. Each commitment consists of a selection of appropriate lexons and a limitation on their use through the application-specific constraints.

By separating the conceptualisation (lexonbase) from the axiomatisation (commitment), this approach provides more common ground for reuse and agreements. For instance, a business rule stating that each person has exactly one address may hold for one partner's application, but may be too strong for another.

2.6.3 Versioning

As with all things, information systems are in constant flux. Especially in a collaborative setting, where an ontology serves as a mediating instrument, will we find a high and continuous need for proper versioning and evolution management. DOGMA incorporates proper support for these issues through the use of change operators, change logs and context dependencies. This includes detailed Meta information such as the name of the contributor, time, date, and appropriate commentary on future changes or possible objections in a project.

3 CONCLUSIONS

In this paper we positioned the features and the underpinning technology of a collaborative platform designed to support the effective cooperation of large-scale enterprises. We outlined the key issues addressed from the specific platform such as the integration of appropriate resources that concur to achieve a cross-enterprise business service and its ability of adapting its integrated features and services according to the project needs.

We are planning to address these issues with a flexible solution based on a methodology that will help avoid the rigidity that usually occurs during the implementation and maintenance stages of existing cooperation platforms. We will perform experiments

with cases from a EU-funded project, where educational institutes and public employment organisations from various EU-countries collaboratively developed a "vocational competency ontology" enabling them building interoperable competency models. Part of this work is currently being published.

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