An Ontology Based Architecture for Integrating Enterprise Applications

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Abstract. Today, companies investigate various domains of collaborative business-to-business e-commerce. They have to look inward to their applications and processes. These applications must be able to cooperate dynamically. This leads to a rise of cooperative business processes, which need the integration of autonomous and heterogeneous applications. However, currently existing approaches for application integration lack an adequate specification of the semantics of the terminology that leads to inconsistent interpretations. In this paper, we propose a formal solution to the problem of application integration and we reflect upon the suitability of the ontology as a candidate for solving the problem of heterogeneity and ensure greater interoperability between applications.

1 Introduction

The integration of information, business processes, workflows and various applications across companies is seen as a viable solution in order to cross organisations and market boundaries and hence enable application deployment in a wide variety of domains, ranging from e-commerce to e-Science Grid projects. As the field of B2B (Business-to-Business) e-commerce grows, we need the question on how enterprises work with their suppliers, customers and other trading partners. This frequently entails the building of new applications by coupling existing ones. This is known as EAI (Enterprise Application Integration). EAI addresses the need to integrate both intra and inter-organizational systems through functionalities from different applications. It supports an efficient incorporation of IS (Information Systems) into business domain [1].

The problem of application integration is already complex due to diverse requirements and heterogeneity of data, processes and applications. Heterogeneity may exhibit in the use of different programming languages, availability on different hardware and operating system platforms. In addition, the heterogeneity emerges in the use of various representations for the exchange of data the use of different approaches

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for modeling applications. However, these applications were not developed to be integrated. They were created independently and thus; do not share the same semantics for the terminology of their applications models. This lead to inconsistent interpretations.

In our context, integration is the process of linking heterogeneous applications, to make a unit complete and confers to it properties related to the interoperability and the coherence of IS. Many attempts have been made to integrate different IS. In most approaches, the remaining problems are still twofold. They are developed for specific business sectors and they do not cope with the challenge of incorporating semantics into applications [5][6][10]. An architecture based on an ontology is often seen as new solution providing exchange facilities of semantically enriched information. It supports mapping process for integrating local ontologies related to heterogeneous and distributed applications. For us, ontologies should be used for two main reasons: first, for modelling the application's structure and behaviour in a precise and rigorous way and second, for representing vocabularies and providing semantic rules of mapping in order to integrate enterprise applications [6].

In this paper, we propose an architecture for applications integration having two levels: applicative and collaborative ones. This architecture is based on a mapping approach to bridge applications ontologies. It supports several heterogeneous applications accessing multiple local ontologies. A component, named mapper, generates a global ontology for managing the enterprise information heterogeneity based on the semantic bridges concept. A semantic bridge encapsulates all required information to translate instances of the source entity to instances of the target entity. So, the integrated applications can successfully and efficiently communicate and exchange information as well as services.

The structure of the paper is as follows: section 2 presents some characteristics of the EAI domain, interoperability and ontology. In section 3, we address some related work. Section 4 shows more details on our architecture, gives a description of the mapper for bridging the application ontology and its main components. Then, section 5 describes our application integration process based on UML class diagram and the description logic formalism. Section 6 concludes our paper and sketches some future work.

2 An Overview of EAI, Ontology and Semantic Bridge

Integration is now seen as a challenge of the information and communication technology field. It is a new research area and many related issues are still under investigation. EAI is the process of adapting a system to make distributed and heterogeneous applications work together to carry out a common objective [2]. In companies, the essential requirement for heterogeneous and distributed IS is to be able to exchange information and services with other ones in a semantically rich and sound way. Thus, semantics should be captured, verified and used to validate reliable information exchange. This is commonly referred to as the problem of interoperability. Ontology is an appropriate way to enable interoperability. It includes an explicit description of both a domain structure and the related terms describing this domain. It allows applications to agree on the terms they use when communicating.

The main purpose for building the application ontology is to capture information about the application structure, behaviour and domain. This information will allow us to elaborate a communication framework. The latter aims to support data interchange and communication processes. One important step in this direction is the reuse of the mapping information based on semantic bridge to enhance the system requirements.

Semantic bridges are appropriate and useful to represent ontology mapping. A semantic bridge considers different dimensions, each one describing a particular aspect [3]:

- *Entity*: this dimension reflects the type of ontology entities being bridged (e.g. classes, properties and relations).
- *Cardinality*: this dimension reflects the number of ontology entities being bridged (1:1, 1:n, n:m).
- *Structural*: this dimension reflects the way whose the elementary bridges may be combined into more complex bridges (specialized, abstract, composed or alternative bridges).
- *Constraint*: this dimension reflects constraints applied during the execution phase to instances from the source ontology.
- *Transformation*: this dimension reflects how the instances of source ontology are translated during the mapping process.

In our work, it is still necessary to take into account the fact that the addition of a new application will require a constant process of integration so that ontology remains adapted to the enterprise evolution.

3 Related Work

Much research has been done in the area of ontology integration with specific focus on the heterogeneity. Solving this problem in ontologies is therefore a desirable goal for many integrating approaches. Heterogeneity can be broadly distinguished into non-semantic (syntactic) and semantic. Syntactic heterogeneity denotes the difference between the language primitives that are used to specify ontologies, while semantic heterogeneity denotes differences in the way that the domain is conceptualised and modeled. Mismatches caused by semantic heterogeneity occur when combining ontologies, which describe domains that partially overlap. Semantic heterogeneity occurs when there is a disagreement about the meaning and the interpretation of the information [7]:

− *Different names* for the same content (e.g. synonym, for instance client and customer).

− *Different value* domains (for instance different measures of temperature Fahrenheit/Celsius, hours/minutes).

− *Different abstraction* levels (e.g. generic terms vs. more specific ones, for instance name vs. first name and last name).

− *Different structures* about the same contents (e.g. type or part of a type, for example date vs. day, month and year).

Numerous approaches for ontologies integration can be identified [4], [5], [6], [10], [12]. In the single ontology approach, a global one provides a shared global ontology to specify the semantics. All information sources are related to the global ontology i.e. they are unified. The global ontology can be a combination of modularised sub ontologies [10]. This approach increases considerably the maintenance tasks if there are modifications in the local ontologies. In the multiple ontology approach, each information source has its own local ontology that can be developed independently. To integrate them, the ontologies must be brought together by finding a set of mapping rules between them, alignment of concepts and relations to indicate equivalence [4],[12] or by translating one ontology into another one [5]. In the hybrid approach, the basic features of the two other approaches are combined. The global ontology is obtained by merging the existing ontologies in a common one that includes all aspects of the individual ontologies [6]. The only really realistic possibility is the mapping approach because in this case the integrated ontologies are not affected.

4 Application Integration Architecture

In the system, we identify several types of legacy, client/server and Web applications, developed using different programming languages. They work on different operating system platforms and use various format for the exchange of data. By using application ontologies, we enhance communication between applications, for the benifit of integration. Hence, ontologies serve as stable basis for understanding the requirements for the user applications.

The integration system we propose aims at offering a support for integrating heterogeneous and distributed applications, accessing multiple ontologies (Fig. 1). It provides a communication framework as a central service. It permits an appropriate exchange of information between applications ontologies and generates the global one. The introduced framework tries to enhance the ontology mapping which enables the reuse of mapping information for managing heterogeneity. The integration process is based on the semantic bridges to indicate the semantic equivalence of ontology entities for assembling them. These applications are linked seamlessly to partners, vendors and suppliers through a common interface.

Furthermore, we give an overview of the two-level approach for application integration, the applicative level and the collaborative one:

− Applicative level consists of heterogeneous and distributed applications. Each application has its own local ontology. Our important direction is the development of a communication framework for ontology mapping. In our architecture, we aim to overcome the gap between local ontologies application, according to the semantic relations. A special component, named mapper, is invoked to perform its tasks for building the global ontology. The latter can be seen as an enterprise ontology and permits the resolution of semantic conflicts in both concepts and attributes.

− Collaborative level takes place in the business process collaboration with partners. Each company has a mobile agent selecting the best partner basing itself on criteria (e.g., price limits, product configurations or delivery deadlines) and using its collaboration scenario for achieving business process. The mobile agent permits to perform the integration tasks according to a process ontology and using an optimized itinerary. The latter improves the performance of the system and reduces the response time.

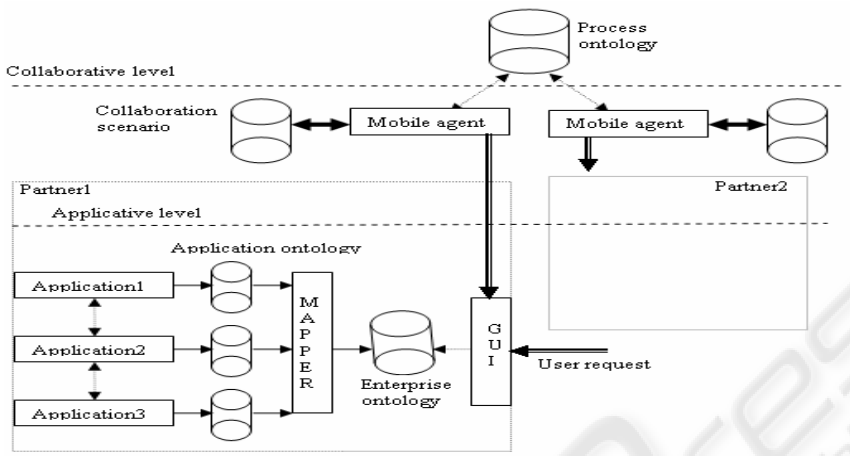


Fig. 1. Integration system architecture.

Further components of the architecture are the collaboration scenario and the process ontology. The latter includes information about the business processes, the organizational constraints, the customer profile and the business constraints. Collaboration scenario are inspired from the ebXML (electronic-business XML) [3] for providing an interoperable framework.

The focus of this paper is on the applicative level as well as building and integration of the application ontologies. Additionally, an overview of the mapper component is given in the following. The mapper component has four parts:

− The *identifier* is used to discover the related concepts or attributes of ontologies and the relations between them. This can be done automatically or manually with the help of domain experts. For instance, it can use lexical ontologies such as WordNet or domain specific thesauri to define the synonym and the antonym relations [8].

− The *adaptor* is used to represent the identified equivalence relations between ontologies based on the semantic bridges. It combines many algorithms to measure the similarity. It adopts a multi-strategy approach to calculate the concepts similarity in various levels, such us lexical, properties (role and attributes), hierarchical and instances similarities. Then, the adaptor checks domain and cardinality inclusion.

− The *linker* transforms instances from the source application ontology into instances of the target application ontology by evaluating the equivalence relations defined earlier by the adaptor. The missing mappings can be gained through inference mechanism.

− The *communicator is* used to enhance the communication between global ontology (enterprise ontology) and local ones (application ontologies). It is responsible for information exchange to answer the user request using the appropriate mapping. It translates the query sent by the user to an equivalent one. This is done by using the mapping information in order to facilitate the query interpretation, according to the concepts of the concerned application ontology.

5 Application Integration Process

Application integration process based on ontologies is a new approach that has rapidly been developed with the emergent Semantic Web [2]. This is mainly due to the fact that ontology is the best way to enhance interoperability and integration of heterogeneous applications. We propose a process for integrating the applications that is characterized by the iteration in order to consider the addition of a new application and the evolution of company requirements and market criteria. The proposed process is divided into four basic steps: capturing, building, integrating and exploiting.

The suggested process is doted by two sub-processes, essential for ontologies building and integration. The first one is building the applications ontologies following many steps, from meta-modeling to implementation. The second one is the integration of ontologies in order to better obtain the enterprise ontology. Our process is complete, i.e., starting from collecting the applications needs and ending at a global ontology.

5.1 Capturing Requirements

A company model is a computational representation of the structure, activities, processes, information, resources, people, behaviour, goals and constraints of the business. This step consists of taking note of the field of integration while identifying the applications behaviour as well as the relations which they maintain between them. The purpose of this step is to capture the sets of applications of the enterprise, the activities that they perform, the resources required by these activities, the manipulated data and the messages invoked them. Then, we identify the flows of information, their structure and the technical infrastructure to support them. To develop the corresponding ontologies, we make this information available to the designers. This step is carried out by the industrial specialists that are expert in the market domain.

5.2 Building the Application Ontology

A range of methods and techniques have been reported in the literature regarding ontology building methodologies [15]. Mike Uschold’s methodology [16], Michael Grüninger and Mark Fox’s methodology [17] and Methontology [18] are the most representative. Grüninger methodology is only limited to ontologies using first-order-logic languages [2]. Uschold’s and Methondology have a common that they start from the identification of the ontology purpose and the need for domain knowledge acquisition. Uschold proposes a codification of knowledge in a formal language. In Methondology, a set of intermediate representations independent of the formal language to be used is expressed. For our purpose, we have chosen the UML language

[3] to represent the concepts hierarchy and how they are related. So, the UML class diagram is used as a meta-model of the application ontology.

Meta-Modeling Application. Let us notice that we retain the logical structure in layers where each application is made up of data and the activities managed by a user interface. The concepts of the application ontology are represented as a set of UML [3] class diagram in Fig. 2. UML is a good and a powerful modeling language for designing object oriented applications. Ontologies include class/subclass hierarchies, relationships between classes, class attribute definitions and axioms that specify constraints. This information is usually modeled in class diagram, the reason why UML is a promising notation for ontologies. Our ontology makes it possible to offer on the one hand, a framework of meta-modeling the applications to be integrated and on the other hand, an intelligent layer used to manage semantics related to the various concepts used.

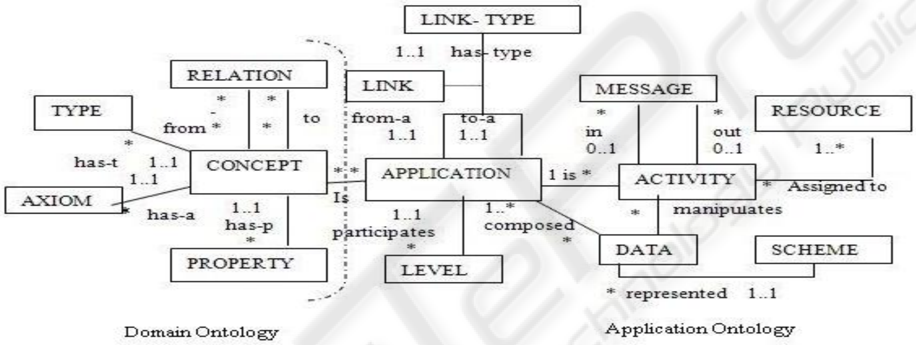


Fig. 2. Meta-model of application and domain ontologies.

The domain ontology gives a formal representation of concepts of the studied domain as well as their relations. However, the domain ontology cannot describe specific fonctionnality and the differences between different applications in a given domain. It attempts to find the set of concepts covering the domain. In our work, we are considering business enterprises which provide products and services for partners and potential customers. We identify two overlap domains, sale and purchase.

Let us give a description of the concepts of the application ontology (Ont):
Ont = (Link-type, Level, Activity, Data, Concept, Relation, Type, Axiom, Property, Resource, Message, Scheme)

− *Link-type.* It is a concept that describes some characteristics of the application related to other applications. It includes partner collaboration, data sharing and service exchanging.

− *Level.* This concept shows the level where application participates to answer customer/partners needs, collaborative and/or applicative.

− *Activity.* This concept captures all functionalities that the application can do. It contains the activity properties such as : message in / message out, pre-condition, activity type, sub-activities, time-begin, time-end and resource assigned.

− *Data.* This concept includes the local/global data manipulated by the application, like type, access right and schema.

Let us remark that starting from the diagram of class (Fig. 2.), the instantiation will vary according to applications. In particular, each application can have its own activities, its data and the role to play in the company.

Formalization. The formalization implies the representation of the ontology in DL (Description Logic) formalism [13]. We consider the SH [12] family of DL as equivalent to the ALC DL [12], extended with transitive properties and property hierarchy. The latter is important for OWL (Ontology Web Language) [12] as it is a feature of RDFS (Resource Description Framework Schema) [9]. Members of the SH family include the SHOQ(D) DL. This language has the ability to define a class by enumerating its instances and support for datatypes and values. Because OWL includes datatypes, the semantics for OWL is very similar to that of DL that also incorporate datatypes, in particular SHOQ(D). We use it to describe the concepts and the roles represented in the UML diagram (Fig.3.). We illustrate in capital letter the concepts and in minuscule the roles. For the SHOQ(D) constructors [24], *atleast* and *atmost* show the min and max cardinality, inverse means the inverse role. We give some rules related to the meta-model in Fig 2.

CONCEPT :< (***all*** *has-a AXIOM)*
*AXIOM:< (****all*** *(****inverse*** *has-a) CONCEPT)*
CONCEPT :< (***all*** *has-p PROPERTY)*
*PROPERTY:< (****all*** *(****inverse*** *has-p) CONCEPT)*
CONCEPT :< (***all*** *has-t TYPE)*
*TYPE:< (****all*** *(****inverse*** *has-t) CONCEPT)*
CONCEPT :< (***all*** *from RELATION)*
RELATION:< (***all*** *(****inverse*** *from) CONCEPT)*
*CONCEPT :< (****all*** *to RELATION)*
RELATION:< (***all*** *(inverse to) CONCEPT)*
*APPLICATION:< (****all*** *(****inverse*** *is1) CONCEPT)*
*APPLICATION:< (****all*** *participates LEVEL)*
*LEVEL :< (****all*** *(* ***inverse*** *participates) APPLICATION)*
*APPLICATION:< (****all*** *composed DATA)*
*DATA :< (****all(inverse*** *composed) APPLICATION)(* ***atleast*** *1 (****inverse*** *composed))*
*APPLICATION:< (****all*** *is ACTIVITY)*
ACTIVITY:< (***all*** *(* ***inverse*** *is) APPLICATION)*
*APPLICATION:< (****all*** *from-a LINK-TYPE)*
*APPLICATION:< (****all*** *to-a LINK-TYPE)*
*LINK-TYPE :<(****all*** *(****inverse*** *has-type) LINK-TYPE)*

Implementation and Test. The implementation deals with building a computable model. The effort is concentrated on the suitability of the OWL DL [9] which is equivalent to the SHOQ(D) [9]. For checking, we need to use the inference services provided by many systems such as FACT [9], RACER [10] and DLP [9]. These systems have shown to work well in realistic applications and to be able to reason with large ontologies. The use of the RACER system can make possible to read OWL file and to convert it in the form of a DL knowledge bases. It can also provide inference services. To manipulate the application ontology, PROTEGE-2000 [21] offers a convivial graphical user interface.

Adaptation and Evolution. Ontologies may change over the time or may be adapted for applications specific needs. Therefore, mechanisms which can discover changes recognize different versions are required (e.g. PROMPT, [7]). Ontology versions may not be compatible with each other. So, information must be available to facilitate discovering changed ontologies. OWL provides some built-in constructs to mark version compatibilities.

For managing the evolution of ontology, a classification takes place once a definition of concept is newly created. For this purpose, we propose the use of the DL classification algorithm.

5.3 Integration of Applications Ontologies

In order to achieve an ontology-based semantic integration, we propose a sub-process that includes several main tasks: comparison, bridging and inference.

− *Comparison* consists of comparing each ontology concept A with each ontology concept B and of determining a similarity metric. We adopt a multi-strategy process [4] which computes similarities between ontology entities using different algorithms. Using just one approach is unlikely to achieve as many good mapping candidates as one we combine several approaches. The first one focuses on acquiring a lexical similarity. The next step computes the so-called property similarity that is responsible to acquire the similarity between concepts based on their properties, either attributes or relations. Then, we propagate the similarity to other parts of the taxonomy, the super and the sub-concepts. Then, we check domain and cardinality inclusion.

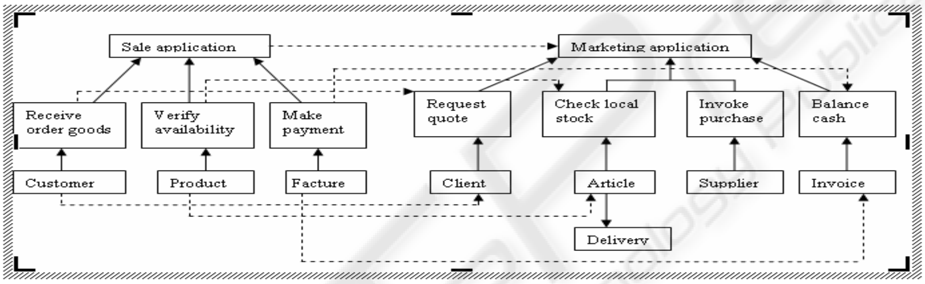
− *Bridging* is responsible to establish correspondence between entities based on the similarities computed previously. Each instance represented according to the source ontology is translated into the most similar instance described according to the target ontology. It intends to associate a transformation procedure to the translation.

− *Inference* mechanism is used when the source concept has not a target concept, which means the source concept has not a direct counterpart in the target ontology.

Example. Let us consider a small part of two different ontologies (cf. Fig 4). The first ontology (O1) describes a sale application (Activity: receive order goods, check availability, make payment; Data: customer, product, facture). The second one (O2) characterizes a business application using a very simple approach (sale, purchase). First, the mapping must define the two ontologies being mapped. We start with the sale-marketing bridge.

< Mapping rdf : ID= “ mapping”>

<relatesSourceOntology rdf: resource=”&O1 ;”/>
< relatesTargetOntology rdf: resource=”&O2 ;”/>< has Bridge rdf: resource=”# Sale-Marketing”/>
</Mapping>
We present the semantic bridge between source concept, product and target concept, article:
<bridges: One2One ConceptBridge rdf : ID =”product- article”>
<bridges : relatesSourceEntity rdf: resource= “&so; product”/ >
<bridges : relatesTargetEntity rdf :resoure“&article”/>
<bridges: accordingToTransformation rdf : resource =”&serv; construct”>
<bridges : hasBridge rdf : resource=
“# productconcern-Marketingapplication_ in check local stock activity”/>
<bridges : hasBridge rdf : resource=
“# productconcern-Marketingapplication_ in delivery activity”/>
</bridges: One2One ConceptBridge>



Composition relation Semantic bridge link

Fig. 3. Example of two application ontologies.

Protégé [21] is an open source ontology development environment with functionality for editing classes, slots (properties) and instances. The current version of Protégé (3.1.1) is highly extensible and customizable. We have used it for developing the two ontologies find in the example. Actually, we focus on the OWL build-in constructs to build the global ontology. For the mapping process, the most interesting build-in of OWL is *owl: sameAs,* which is used to specify that two entities identified by an URI, refer to the same individual. Classes can be treated as instances, owl*: sameAs,* can also be used to define class equality, thus indicating that two concepts are equivalent.

5.4 Exploitation

This step deals with the realization of the computational model of integration, which makes it possible to link the enterprise applications. Once the system is deployed, it remains us that to maintain the technical infrastructure of integration. Furthermore, this step covers the exploitation of the integration system. This function is not limited by time. It is necessary to address the evolutions of the enterprise (e.g. integration of a new application) and to manage the ontology versions.

6 Conclusion and Perspectives

The problem dealing with heterogeneity, even semantic has been deeply investigated in the field of ontology.

We proposed an ontological approach for integrating company applications. This approach enhances application integration at both applicative and collaborative levels. For the first one, we called upon the mapping process based on the semantic bridges for integrating local ontologies. For the second one, we give more attention to the partners' collaboration using common process ontology and mobile agents for ensuring interoperability. The important benefit of our work is that the communicator can reuse the mapping information for managing interaction between applications.

We are currently developing local and global ontologies basing on the mapping process and facilitating the exchange between them through the communication component. We intend to design the process ontology and evaluate the approach in the e-business domain.

Future work will focus on the development of the collaborative level. Our attention is related to the ebXML [3] collaboration scenario in order to offer an interoperable infrastructure for business collaboration. Furthermore, the ebXML collaboration scenario will be extended by mobile agents in order to search the appropriate partners and negotiate business parameters (product price, delivery time, …). For application ontologies, we can address some perspectives: (i) experimentation to validate the integration process; (ii) using the framework MAFRA [4] to support the application integration; (iii) improving concepts and properties similarities basing on semantic aspects.

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