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VIRTUAL ORGANISATION IN CROSS DOMAIN ENGINEERING

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In order to be able to develop new products in a growing competitive environment the modern SMEs face a number of challenges: how best to design and innovate, how to understand constantly shifting customer needs, how to produce the products that meet those needs within tight budget and time constraints. Forming networks through co-operation between different companies (virtual organisations) has become an important business strategy for SMEs to respond to these challenges. The paper discusses new approaches to support cross-domain engineering and cross-enterprise collaborations with help of a modular framework, providing an integrated view of the relevant information. The result of the research carried out is a partly implemented framework for intercultural and cross-domain collaboration, based on the ontology-supported common understanding between the partners within a virtual organisation.

1 INTRODUCTION

The recent trends in development of modern complex products define the development process as cross-domain collaboration between the enterprises. Efficient collaboration over different domains (here: mechanics, electronics and (embedded) software) leads to a much higher competitiveness capability of the enterprises in the distributed and networked information environment. This becomes particular apparent in the industrial sector of the automotive industry which takes a guiding role for future trends in the industry. This brings about the prospect of ad hoc integration of systems across organisational boundaries to support collaborations that may last for a single transaction or evolve dynamically over many years. This sets new requirements for scalability, responsiveness and adaptability that necessitate the on-demand creation and self-management of dynamically evolving virtual organisations (VO) spanning national and enterprise borders, where the participating entities (enterprises or individuals) pool resources, information and knowledge in order to achieve common objectives.

One of the possible ways to respond to these challenges is to use context ontologies. Their wide usage in different application domains is based on their capacity to enable a shared common understanding of a domain between different agents (people, application systems, communities).

2 PROBLEM DEFINITION

Collaboration between companies and enterprises is often initiated only for a certain task and therefore is dynamic and short termed – in other words, this is a virtual organisation. Nevertheless information which has to be shared within the collaboration process gets more complex and is distributed across heterogeneous system environment. This requires methods and tools which allow the management of distributed data and an efficient integration of legacy systems. The main problem addressed by the paper is the lack of efficient tools for cross enterprise and cross-domain engineering processes.

There are highly specialised tools available for each engineering domain (e.g. PDM[1]-Systems, E-CAD[2], M-CAD[3], MBS[4] etc.). But existing solutions for bridging between domains are still rare and inefficient. The framework presented in this paper does not aim to replace any specific domain tool but to bridge between the domains. Therefore it is necessary to adapt the existing applications. The highly specialized domain tools overlap only partly over the domains concerning the offered functionality and underlying semantics. There are several software solutions on the market (e.g. PDMConnect (PDMConnect), OpenPDM (OpenPDM, 2005), SAP NetWeaver (NetWeaver, 2005), IBM WebShere (IBM, 2005), MS Bizztalk (Anderson, et al., 2000)) which allow the exchange of product data across the border of enterprises. The focus of these solutions is to exchange data between certain systems of one domain. These solutions do not able to provide an integrated view on the exchanged data, but allow a mapping of data structures between the involved systems. Thus important information is lost within the exchange process within cross domain communication since the target system is not able to “understand” all information needed within the collaboration.

3 OBJECTIVES

The software framework presented in this paper is subject of the research EU funded research project ImportNET[5]. The ImportNET open source framework aims to actively support of cross-domain and cross-enterprise collaborations with focus on SME networks. In order to setup collaboration where engineers of several domains and different enterprises are involved, it is necessary to have a common understanding of the relevant data and processes. An Ontology describes a certain domain and provides a common understanding within that domain. The problem of the use of ontologies (e.g. semantic web) is that there is no “unique ontology” which is valid and describes all relevant facts. The idea within our research is to (semi-) automatically derive an ontology which is valid only within collaboration (collaboration ontology) based on reference ontologies which are available within the internet or standardisation organisations (E.g. STEP[6] (STEP, 2005), IDF[7] (Kehmeier, 2006) etc.). The collaboration ontology describes not only artefacts (data elements) but also processes and services and therewith builds a coherent description of all terms relevant within the collaboration.

In the context of system integration various research prototypes (e.g. A3 module of ATHENA project (Ruggaber, 2005)) have been developed to enable a semi-automatic model matches between systems (Mahl, 2005). This tools use different

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[1] PDM: Product Data Management
[2] ECAD: Electronic Computer Aided Design
[3] MCAD: Mechanical Computer Aided Design
[4] MBS: Multi Body Simulation
[5] ImportNET: Intelligent modular open source Platform for intercultural and cross-domain SME Networks (see: http://www.importnet-project.org / 6th Framework).
[6] STEP: Standard for the Exchange of Product Model Data. STEP is a synonym for the ISO standard series 10303 "Product Data Representation and Exchange"
[7] IDF: Interchange Definition Format

approaches like neuronal networks, rule bases, etc. (Semenenko, 2004). Up to now the achieved results are not sufficient for commercial use. This is mainly because they attempt to provide "general solutions" independent from the domains. Thus the approach within ImportNET uses background knowledge about the domains of the IT systems to be connected. At the first part the paper outlines a concept of a generic, modular framework which provides an integrated view of the relevant information. The second part of the paper outlines the stages of the setup of a working environment for a collaboration based on the ImportNET framework.

4 IMPORTNET MODULAR FRAMEWORK

4.1 Framework architecture and components

The main result of ImportNET will be a software framework which actively supports following issues:

- Reduction of the complexity of the information to be shared within the collaboration by automatic derivation of the minimal needed collaboration ontology. Setup of the semantic integration of proprietary systems using the collaboration ontology as common semantically basis – setup phase
- Execution of cross domain product development process by providing domain oriented representation of the relevant information (based on the collaboration ontology) – execution phase.

In order to reduce the complexity of the information it is necessary to customize the common ontology according to the need of the collaboration. The ImportNET approach deals with a collaboration ontology (based on reference ontologies) which is valid only within the collaboration. These ontologies will cover the most important concepts of the domains mechanics, electronics, and informatics. The Semantic Application Server (SAS) is the core of ImportNET framework and realises the ontology based access to the information stored in proprietary systems. The general architecture of the framework consists of four main components, described below (see Figure 1).

ImportNET provides a method and a software tool (Ontology Integration Tool (OIT)) which facilitates the specification of the collaboration ontology. The common ontology will be used to automate the development of an adapter of an external system (E.g. PDM system). Therefore a methodology and IT-tool (Intelligent Adapter Generation Tool (IAGT)) will be developed which uses up-to-date approaches of intelligent software applications (e.g. data mining, neural networks etc.) and semantic model matching approaches in order to analyse the API (and underlying data model) of the external system. This will reduce the financial and time consuming manual implementation effort and will speed-up the establishment of collaborations.

The Semantic Application Server (SAS) provides an ontology-based semantic representation of the distributed collaboration data. Thereby the SAS enables an easy development of business applications which have to access distributed data. While the modules OIT and IAGT will be used for configuration issues in order to prepare the collaboration, the SAS manages the IT-support in the collaboration.

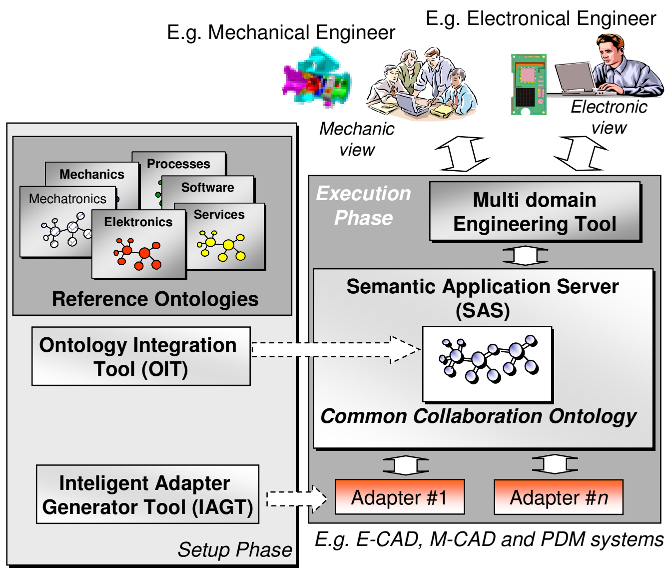

Figure 1: ImportNET framework architecture

The Multi Domain Engineering Tool (MDET) realises an ontology based visualisation of the information that is relevant in the collaboration, corresponding to the engineering domain and cultural background of the user. Information to be visualised could be e.g. product structures, simulation data (multi-body and finite elements), etc. Furthermore, the client will also provide functions for changing the information and trigger new (time consuming) computations. The Multi Domain Engineering Tool represents a generic viewing component which will satisfy requirements resulting from cross engineering tasks (regarding visualisation). Therefore MDET provides a significant improvement of providing cross domain (mechatronic) and cross cultural engineering processes.

4.2 Setup phase of the ImportNET framework

After two or more SMEs have agreed to work together in a cooperation project, there is the need to setup the infrastructure for the collaboration. Within the setup phase two main actions needs to be done (see Figure 2). Firstly the collaboration ontology and therewith the specification of the relevant artefacts (data model elements), services and processes needs to be derived from reference ontologies. This task is provided by the OIT. Secondly the external systems of the collaboration partners need to be connected to the SAS. This is done by implementation of adapters. The implementation of the adapter is partly generated automatically using the Intelligent Adapter Generation Tool (IAGT). The IAGT analyses the semantic models of the external systems and generates source code for the semantically mapping between the external models and the collaboration ontology. If the semantic model of the external system is not available it needs to be derived by analysing the API or defined manually. The rest of this section deals with the question how to derive the collaboration ontology.

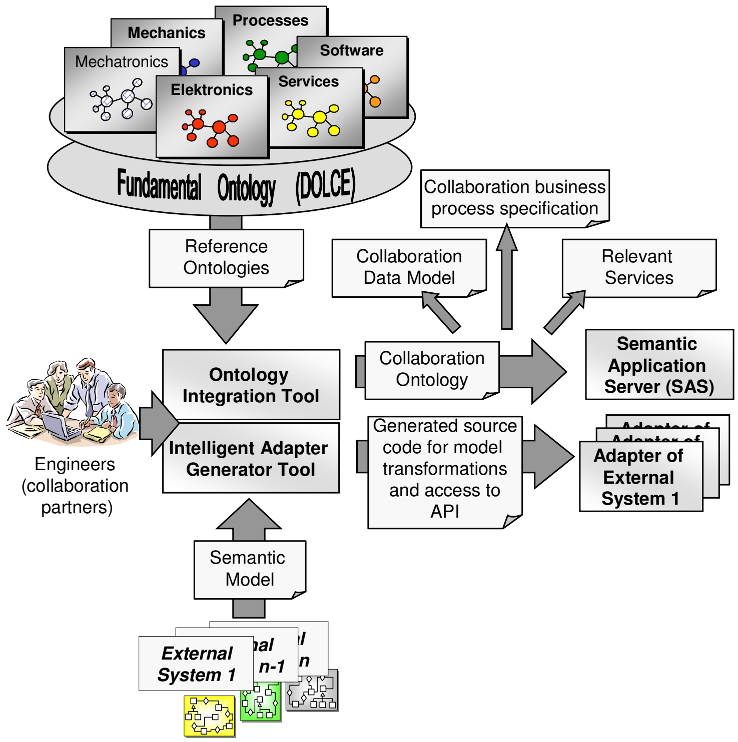

Figure 2: Setup of infrastructure for a collaboration

Figure 3 shows the necessary steps to derive the collaboration ontology and therewith the artefacts (data items), services and processes used within the collaboration. Based on the issues carried out in the collaboration preparation (e.g. specification of business process and initial product structure etc.), the essential concepts on the reference ontology are denoted manually. Subsequently, the collaboration ontology is derived automatically by using semantic hull algorithm (Mahl, 2007). The ontology may be manually extended by concepts that are not available in the reference ontologies. The OIT provides modules for transformation of the collaboration ontology (specified in OWD-DL) into standard representations.

The ImportNET reference ontology uses the task ontology DOLCE (Mika et. al., 2004) as its fundamental ontology. The process domain of the reference ontologies contains a description of reference processes potentially supported by services offered by the ImportNET framework. Thus it is assumed that the transformation between the ontology based representation and a standard representation (here: Business Process Execution Language (BPEL (2003))) is bidirectional. Up to now we did a prototype implementation which allows a bidirectional transformation for a subset of BPEL. The BPEL representation of the process will be used within the workflow engine of the SAS. The SAS implementation does not provide its own domain data model but a meta data model which allows to specify (and modify) the data model on runtime. Based on its XMI representation the data model for the collaboration will be established in the SAS. The (collaboration) data model represents the artefacts of the engineering domains which need to be stored in a data base. The data model is an "implementation oriented semantic model" whereas the collaboration ontology could be seen as "end-user oriented semantic model". Within the transformation towards the data model no semantics will be lost, but the data model will be optimized in the context of implementation (no deep class hierarchy etc.).

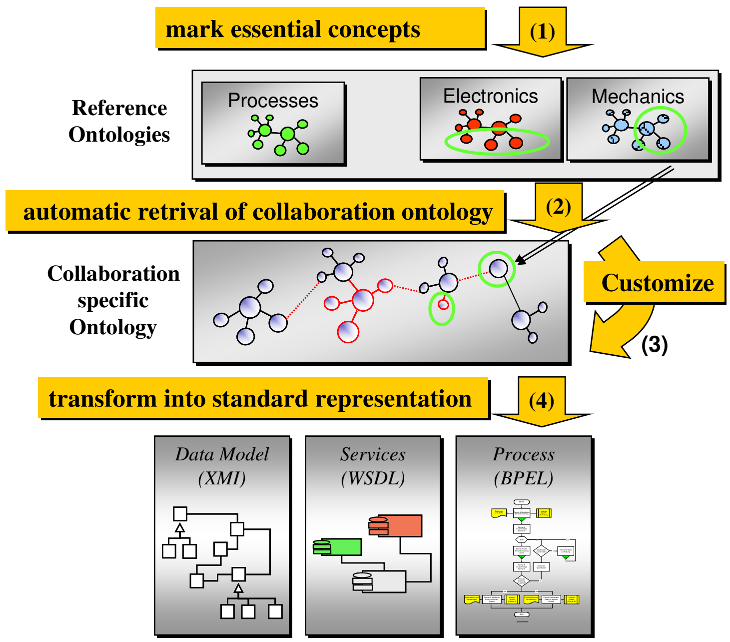

Figure 3: Derivation of collaboration ontology and standard representation for processes, services and data model

That means after the collaboration ontology has been derived semi-automatically by the OIT and experts of the engineering domains a software expert generates the data model using the OIT. The software expert specifies for example which concepts will be represented by an object type and which by an attribute of the object type of its super concept. For example in the collaboration ontology there is the concept "inductor" which is a subconcept of the concept "part". In the data model there will only be an object type "part" with an attribute "type". The attribute may have the value "inductor" (or the name of any other subconcept) in order to indicate that the instance of the object type part is an inductor.

Now we focus on step 1 of the derivation process (see Figure 3) for the collaboration ontology: manual selection of the essential concepts. Since the experts of the involved engineers (domain experts) are usually no ontology modelling experts this task needs be supported by a software tool (OIT) and should not be visible for the engineers.

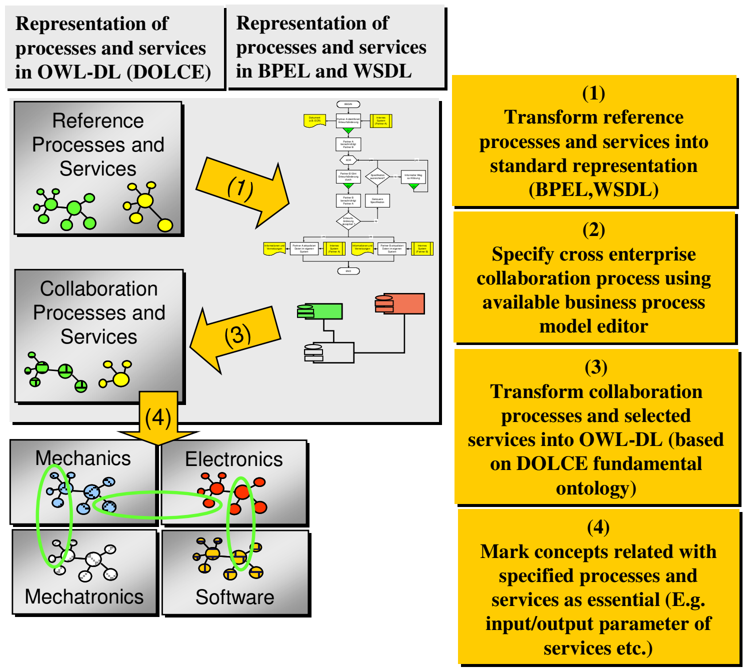

Figure 4: Manual selection of essential concepts by specifying the cross enterprise collaboration process

About 80 percent of the products are developed on former design. The engineer knows in principle the structure of its product (each car consists of four wheels, a chassis, an engine etc.). Thus the OIT provides the functionality to specify the product structure based on pre-defined product structure templates. The engineer specifies the components (E.g. electronic engine, transistor etc.) needed for the product as well as the conceptual structure. Each component has predefined functions and requirements which could be initialized later. For example the electronic engine has got the functions: create power and create heat. Based on the specification of the principle structure a set of concepts is selected as essential. The other concepts are selected during the specification of the cross enterprise business process (see Figure 4).

This approach uses the bidirectional transformation between DOLCE based reference ontology and BPEL. The process domain of the reference ontology contains the specification of reference processes supported by the services of the SAS. Since there are graphical editors for BPEL available the process specification will be transformed into BPEL. Based on the reference processes (and the available services) the business process for the collaboration will be specified. After that the BPEL representation will be transformed back to OWL-DL. Therewith the artefacts relevant for the services or process steps (e.g. input/output parameter for the services or processes) will be marked as "essential". The concepts derived from specification of product structure and business process build a good starting point for the next steps of the collaboration ontology derivation process.

5 CONCLUSION

In the context of dynamic SME networks, the fast installation of virtual enterprises out of the network and the effective and efficient execution of a collaboration network is a critical process for product developing companies. The uniform description of data, processes and services with an approach using ontologies supports the common understanding and builds the base for ontology-based cross-enterprise collaboration process. The cross-enterprise integration framework provides a transparent view on the data, which is relevant within collaboration activities. The platform allows dynamic „on the fly"-integration of external systems. In order to speed up the integration as it was outlined in our approach, we suggest using ontologies to make the integration process more scaleable.

6 REFERENCES

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