TOWARDS A SEMANTIC-BASED PLATFORM TO IMPROVE KNOWLEDGE MANAGEMENT IN COLLABORATIVE PRODUCT DEVELOPMENT

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ABSTRACT

In industrial organisations, the product development defines a significant part of whole production cost. The Knowledge Management at this stage is a major stake in order to reduce costs and time to market, and also to improve the product quality. Product Lifecycle Management stands as efficient approach to integrate the knowledge management in a company, facing to a several challenge: strong networking of companies, knowledge exchange between companies and knowledge re-use. To reach this objective of PLM based knowledge management, an integrated IT platform is proposed. Named I-Semantec, it is based on Semantic Web technologies, to support knowledge modelling and sharing through the whole product lifecycle.

INTRODUCTION

Knowledge Management (KM) is considered as one of the key success factors in industrial organizations. Then, industrial organizations invest more and more to preserve the one of the major immaterial assets: the engineers knowledge and know-how in product development. Using KM strategy, companies will be able to improve the knowledge sharing and cooperative work inside the organization; disseminating best practices in product development; improving relationships with other companies (like in extended enterprise); preserving past knowledge of the organization for reuse; improving the quality of projects and innovations; anticipating the evolution of the external environment; and preparing for unexpected events and managing urgency and crisis situations (Dieng-Kuntz and Matta, 2004).

Product development is an important phase in product lifecycle. It requires several knowledge inputs to realize product and, by consequence, it create a new knowledge. Knowledge inputs are what the engineers know about the product (implicit knowledge) and what the product-related resources contain (explicit knowledge). Resources can be applications, processes, information about the complex product lifecycle. Towards a well exploitation of these resources, Product Lifecycle Management (PLM) stands as an efficient approach to manage the knowledge of a company. PLM helps to organize, track and control access to product information as the information is created and it assists a team-oriented approach to product development (Siddiqui *et al.* 2004). KM is an interdisciplinary approach, and takes into account human science, organization management and information technology issues. The main objective is to obtain a better knowledge management during the product development.

On the one hand, the PLM is facing to several challenges, such as the knowledge exchange and re-use. Each PLM systems manage data in different way and based on data schemes (model and/or database). However, having a common and shared knowledge modelling enables engineers to re-use concepts and core models from past designs in order to overcome time factors on current project.

On the other hand, the Semantic Web offers to KM a new opportunities and technologies in knowledge modelling, knowledge interoperability, and so on. According to (Berner-Lee *et al.* 2001), Semantic Web aims to integrate technologies in a large scale infrastructure that gives to information a well-defining meaning enabling computers and people to work in cooperation.

The following section presents the contribution of the current PLM strategies in Knowledge Management of the company and what goes wrong with them. In section 3, the Semantic Web technologies are detailed including how they can contribute in knowledge management within PLM approach. Then, the section 4 presents I-Semantec, an integrated platform including Semantic Web technologies to improve knowledge sharing, transfer and re-use. Finally, the obtained results and future works are discussed in order with the link of PLM systems and Web Semantic technologies.

PLM IN SUPPORT OF PRODUCT DEVELOPMENT

Product development is a distributed and collaborative engineering process, in which individuals from different expertises and companies cooperate in order to design a product and to specify related manufacturing, assembly or else processes through remote coordination, communication and control (Wang *et al.* 2005). Product design activity is based ono multiple resources: applications, processes, information that define a product. In this context, a mechanism for capturing, coordinating and managing engineering data is required. These data are related to the product, its structure, its life cycle and processes, and used to create, modify and issue the data. So, an efficient way for sharing corporate knowledge through the whole product lifecycle is needed.

Role and benefits of PLM system

Product Lifecycle Management (PLM) is both, an information technology and a strategic approach (CIMdata, 2003) supporting the collaborative creation, management, dissemination, and use of the product definition information across the extended enterprise from concept to end of life - integrating people, processes, applications, and information.

Based on this definition, PLM can be considered as an extended view of Product Data Management (PDM) in its wider significance (Saaksvuori and Immoen, 2004): covering the whole lifespan of the product and the whole spectrum of product data, but not only product-related CAD files. PLM may also be understand as the new generation of PDM.

PLM is supposed to manage all information about product lifecycle in an efficient way. There exist several benefits to implementing PLM:

- improve effectiveness for users: reduce complexity of accessing the information of a company.

- improve interdisciplinary collaboration: suitable manner for developing the internal communication of the company and communication between companies in the partnership network.
- speed the transfer and translation of files and data exchange
- reduce time-to-market

Information managed by PLM comes from multiple systems and based different formats. It includes (Liu and Xu, 2001): geometry, engineering drawings, project plans, part files, assembly diagrams, product specifications, numerical control machine-tool programs, analysis results, correspondence, bill of material, and many more.

PLM challenges in industry

The industrial and engineering world becomes more varied: the growing mobility of the company peoples, the systematic use of service providers, the delocalization of high-tech activities, etc. Thus, the need to communicate and exchanging knowledge is grown.

Knowledge exchange and sharing

According to (Saaksvuori and Immoen, 2004) there are many challenges that PLM must overcome, mainly: strong networking of companies and data exchange/transfer between companies. Indeed, a poor communication between PLM systems and lack of a common integration exist. This leads to a poor knowledge sharing and software interoperability.

Extended enterprises use a remote access to collaborate and to share data. Remote access is very slow when we use client/server application, and it is more efficient when an application Internet-based is used (Liu and Xu, 2001). The bandwidth of Internet influence on the data transfer time, especially the CAD file transferring, what's make it easy to have mistakes during data transferring and lack of the security of the information flow.

Tow kinds of data exchange can be considered: simple data exchange (transfer of CAD files and metadata from PLM source to destination one) and data exchange with translation of CAD files. Therefore, the follow combinations can be found:

- PLMv1 + CAD ➔ PLMv2 + CAD (simple)
- PLM1 + CAD ➔ PLM2 + CAD (simple)
- PLMv1 + CAD1 ➔ PLMv2 + CAD2 (translation)
- PLM + CAD1 ➔ PLM + CAD2 (translation)
- PLM1 + CAD1 ➔ PLM2 + CAD2 (translation)

Usually, the first kind of transfer is used when data exchange from PLM system to another is needed, or between tow versions of the same PLM system. UGS proposes PLMXML as a standard to the simple data transfer between PLM systems (UGS, 2004). In the industrial context of Renault (DocProcess project), this standard has been experimented and it has been issued that the data schema of this format is nearest to the pre-defined data model in the UGS PLM systems. As conclusion the data transfer between PLM remains a real challenge.

Then, the transfer with translation of CAD files has been assessed at several contexts. The diversity and the number of CAD software available make data exchange more difficult so much so that it became necessary to standardize and simplify these exchanges. A numerous formats and standards exist and are available, but every generation of software technologies make them obsolete. STEP (Standard for the Exchange of the Product model data – ISO 10303-1, 1994) is the famous one. It aims to be a neutral, perennial and evolutionary data form. The STEP standard allows to process the representation and exchange of the product models covering the whole product lifecycle. In a survey of these standards by (Eynard, 2005) raise the follow critical points:

- Relative slowness of STEP interface integration in commercial software
- Numerous concepts and information that STEP include, this what's make this standard remain complex to read and understand
- Data associated representation and structuring are not adapted to all format: this requires an additional efforts for adaptation and implementation which may be expensive
- STEP files are voluminous

The volume of STEP files can be reduced without damage or loss manipulated information using a more concise syntax.

<u>Knowledge re-use</u>

We identify another and important challenge in PLM world. It is about the lack of explicit knowledge (products information and components) recycling (re-use).
Currently, there exits no functionality allowing to re-use past experience, or helping to organize the best practices in an efficient way.

PLM systems provides an environment in which all types of information are used to specify, manufacture and support products and in which they are also stored, managed and controlled. The information storage, management and control is based on a data model. Currently, there exists no flexibility to handle data models in PLM system. In other words, the metadata structure is fixed in the database model., Generally, it is a great scale operation to only modify an attribute type in the database (Sriti *et al.,* 2006). The rigidity of PLM system metadata structure is principal gap to re-use knowledge.

In order to improve Knowledge Management during product development a study has be carried out. It focuses on how to get an effective manner to share related product lifecycle knowledge? And, how they can be easily exchange and re-use in similar contexts?

To answer these questions, a survey of some research works in Computer Integrated Manufacturing, Knowledge Management and Knowledge Engineering fields has be done. The idea is to identify the basic constructs that a robust and efficient infrastructure should include to answer the two above questions.

In the next two sections, the result of this study is introduced and the chosen approach to specify the platform is detailed.

SEMANTIC WEB AND INDUSTRIAL INTEGRATION

Knowledge Management aims at capturing explicit and tacit knowledge of an organisation in order to facilitate the access, sharing, and re-use of that knowledge. (Dieng-Kuntz and Matta, 2004). KM helps to identify knowledge of the enterprise, to make them visible, to preserve, to have access to, to maintain, to distribute, to better use and to develop them. Thus, KM process allows to re-use, in relevant way, the corporate knowledge previously modelled and stored in order to accomplish a new tasks (Charlet *et al,.* 2003).

In the past, KM solutions handle textual content of documents as the main source of knowledge. This classic document-based technologies has clearly showed their limits in capitalization of the knowledge assets. And nowadays, several techniques can be considered, according to the type of organization, its needs and its culture: knowledge-based approaches, document-based approaches, workflow-based approaches, CBR-based approaches, CSCW and cooperative approaches, ontology-based approaches, corporate Semantic Webs, Web-based approaches, agent-based approaches, Organizational Memory approaches, etc.

Next shows how the Web Semantic technologies, such as ontology, offer new opportunities to KM solutions within industrial integration.

Principles of the Semantic Web

According to (Terzi *et al.,* 2003) the Semantic Web (SW) is the third generation of the Web (the first one started with the 'hardwritten' HTML web pages, and the second one made a step forward introducing machine to generate HTML pages). What distinguish the Semantic Web from the two previous generations is that its aim to provide a machine readable information.

Semantic Web consists to make the semantic content of the resources interpretable, not only by human but by programs too, for a better cooperation between humans and machines (Berner-Lee *et al.*, 2001). To reach this goal, the SW should rely on a standardisation of the contents modelling in a large *e-space* for resources exchange to better exploitation of these resources.

Thus, the Semantic Web consists to provide a large and distributed communities, infrastructures and services to support these communities. This kind of infrastructure should allow to identify and transform (heterogeneous) resources in robust and safe way. The infrastructure should also guarantee a high level of interoperability automation between different formalism and standards.

There exist several similarities between the SW technologies and the PLM systems. A comparison of the two types of infrastructure is detailed below.

Why an integration of Semantic Web in PLM?

Within product development framework, our main concern is to enhance the knowledge resources managed by PLM systems in the enterprise with a unified formal modelling allowing the end-user to find and re-use efficiently knowledge produced in earlier projects. The content of resources managed by the PLM must be interpretable by the system to be able to answer user requests, that what guides us to choose to the Semantic Web technologies.

Table 1: Technical comparison between SW technologies and PLM platform

Technical criteria	Semantic Web technologies	PLM platform
Content	heterogeneous, dynamic, uncertain	heterogeneous, dynamic, reliable
Architecture	distributed , decentralized	distributed, centralized
Scope of application	huge	big
Security	sharing and secure	sharing and controllable
Openness	more extendable	much more extendable
Interoperability	ontologies, inference engines, applications	PLM, CAD/CAE/CAM, ERP, etc.
Content organization	URI (Uniform Resource Identifier)	database identification keys

Including a (Web) semantic level in product lifecycle will help us to make abstraction of the complexity of the product related resources and provide us a kind of services that enabling reasoning on a conceptual (semantic) modelling.

Table 2: Organizational comparison between SW technologies and PLM platform

Organizational criteria	Semantic Web technologies	PLM platform
Organization	all the web	enterprise and its partners
Profile	different profiles	engineer designers, product experts, etc.
Objective handled information	any information	engineering (product lifecycle)
Resources usage	all usages are unknown	design, production, analysis,

In order to prove the applicability of SW technologies within product development context, the domain knowledge is modelled and formalised (ontology) in order to be the basis of varied processing (reasoning) carried out by machines.

The SW technology maps with PLM methodology on many aspects (see *Table 1* and *Table 2*).

Uniformed knowledge modelling and exchange format

In PLM, there exist several (heterogeneous) sources of (dynamic) knowledge to explore. A huge effort is currently being developed by many communities in order to standardize their contents and data models enabling the integration and exchange of knowledge coming from heterogeneous data sources.

In Web Semantic, the main aspects for knowledge modelling are: *metadata* describing the resources, *resources* containing the formalized knowledge, *modelling languages* intending for a better use, combination, and reasoning on the resources content, and *ontologies* for sharing knowledge and interpreting them by humans and machines.

Metadata provides a concise description of the content meaning (Jun *et al.,* 2005). They enable indexation and classification of resources, makes more robust information search and allowing to apply inferences.

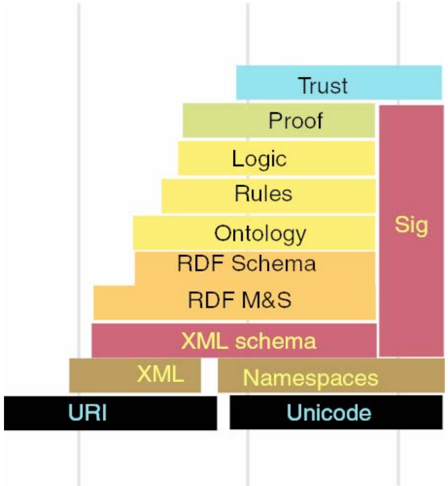

Figure 1: Semantic Web stacks

SW languages are based on metadata concept what makes them an inevitable approach for a rich description of resources content. XML is considered as a basic language for SW modelling (*Figure 1*). It can be mentioned that resources translation and exchange for main SW languages can be formulated in XML syntax.

XML is characterized by a high flexibility to express the content structure of documents. The semantic of the XML document is not expressed; it is implicit and can only be perceived by humans that read document's source code.

RDF (Resource Description Framework - Lassila and Swick, 1999) known as one of the basic models on which the Semantic Web is founded. The real value and the basic definition of RDF is its data model (Terzi *et al.*, 2003). It specifies a very simple data model of triples (subject, predicate, object). In other words, every resources (subject) have a property (predicate) with a given value (object). Based on this simple model PLM objects and their properties can be smoothly modelled. RDF content is controlled with RDF Schema vocabulary that define classes, properties, and their interrelation: they operate directly at the data model (semantic) level rather then the syntax model. This makes RDF most promising candidate as language for a unified modelling of PLM resources.

Ontologies specification

To support the sharing and re-use of formally modelled knowledge within PLM systems, it is useful to define a common vocabulary in which shared knowledge is modelled. Yhis common vocabulary can be structured based on an ontology (Gruber, 1993, Uschold and Gruninger, 1996). Ontologies are more adequate technologies for applications aiming to share and exchange knowledge through a large information systems such as PLM. They are more studied in the knowledge engineering field, and they existed before the SW. Ontology can be considered as a reserve of metadata describing well resources. Ontologies provide a shared understanding of some applications domain and can be formulated by SW languages. They define a conceptual and rigorous organization of concepts about the considered domain. Concepts are described (classes, attributes, functions, rules) and related to constitute a *semantic* *networks*. Instances of the conceptual organization (ontology) constitute a Knowledge Base.

As claimed in (Lamsfus *et al.*, 2005), ontologies have been established as effective and efficient means for knowledge sharing and are being widely used to conceptually model domains of knowledge. The difficulties of poor communication can be solved by the interaction of ontologies. Considering the growing use of ontologies in various application domains, the problem of overlapping knowledge in a common and shared view becomes critical. In such a context, some research works have already been done on developing semi-automated applications that enable the merging, mapping or alignment of ontologies (Noy and Musen, 2003).

Ontologies have a key role in the development of the Semantic Web, and then in the information exchange process.

I-SEMANTEC PLATFORM: INTEGRATION OF SEMANTIC WEB TECHNOLOGIES WITHIN PLM

The main concern of the section is to enhance the knowledge resources managed by PLM systems in the whole enterprise based on an unified formal modelling language. This language aims at allowing the end-user to find and re-use intensively knowledge produced in past projects.

Proposal for a platform enabling collaborative product development

I-Semantec platform is an industrial information system supporting a collaborative product development based on Knowledge Management. I-Semantec proposes realizing a corporate knowledge warehouse:

- Knowledge capitalisation and re-use: Knowledge resulting from the information contained and managed by the PLM system is centralized and structured in a dynamic way in order to enable an intensive re-use in new projects.
- To seek knowledge in a transparent way: The I-Semantec functionalities will allow creating dynamically and collaboratively new ontologies which structure knowledge by taking into account the real needs of the engineers.
- Knowledge sharing: The information currently managed by PLM are organized in order to allow their use within a specific project, it is seldom thinking an organization allowing the re-use of these data in future projects. These data are also often organized according to a defined need: functional requirements, detailed design, manufacture, quality, etc. These various views on the product are seldom interoperable. I-Semantec aims at sharing knowledge by providing an infrastructure and functionalities which:
  - unify modelling format;
  - create in the same reference framework, flexible, dynamic and collective organizations of various sources of information;
  - offer a single search tool.
- The use of metadata and ontologies: The approach of I-Semantec is based on the metadata and data already existing within the PLM systems, and aims to

enrich and reorganize them by ontologies flexible, dynamic, multiple points of view and built collaboratively.

Knowledge Management approach of I-Semantec

The current evolution these works enables to specify the architecture of I-Semantec adopting a generic method (*Figure 2*) for knowledge management (identify, capture, model, validate, store, distribute and maintain). The bases of the platform is the level of its flexibility (ontologies modelled with RDF), extensibility (modular architecture) and the high degree of interoperability with other tools.

The product lifecycle related data and metadata are extracted and translated into RDF format. In the case of a multiple extraction from different PLM system, it should be kept one model in the knowledge base. The data models are combined and data are integrated into knowledge base following a defined mapping process. Then, knowledge base content will be more easily usable and maintainable.

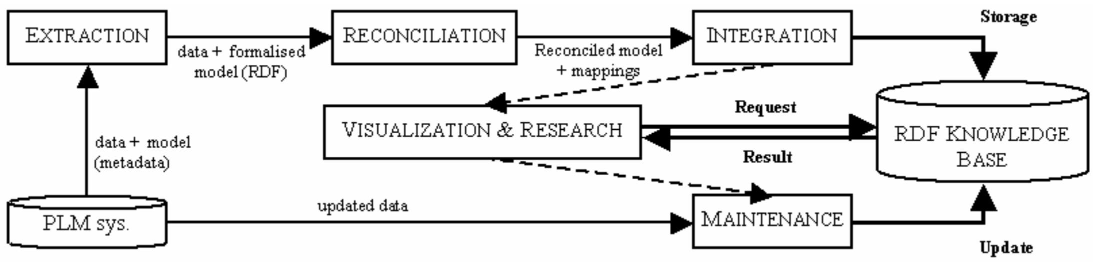

Figure 2: Knowledge management process within I-Semantec

Architecture of I-Semantec

A PLM system (Knowledge source) is composed of a relational data base, a vault (a secured repository for files storage) and an man-machine interface by which the user can access to data and documents. Via I-Semantec, the resources resulting from the product lifecycle traverse three essential phases (extraction, combining and integration) before being at the disposal of the users (*Figure 3*).

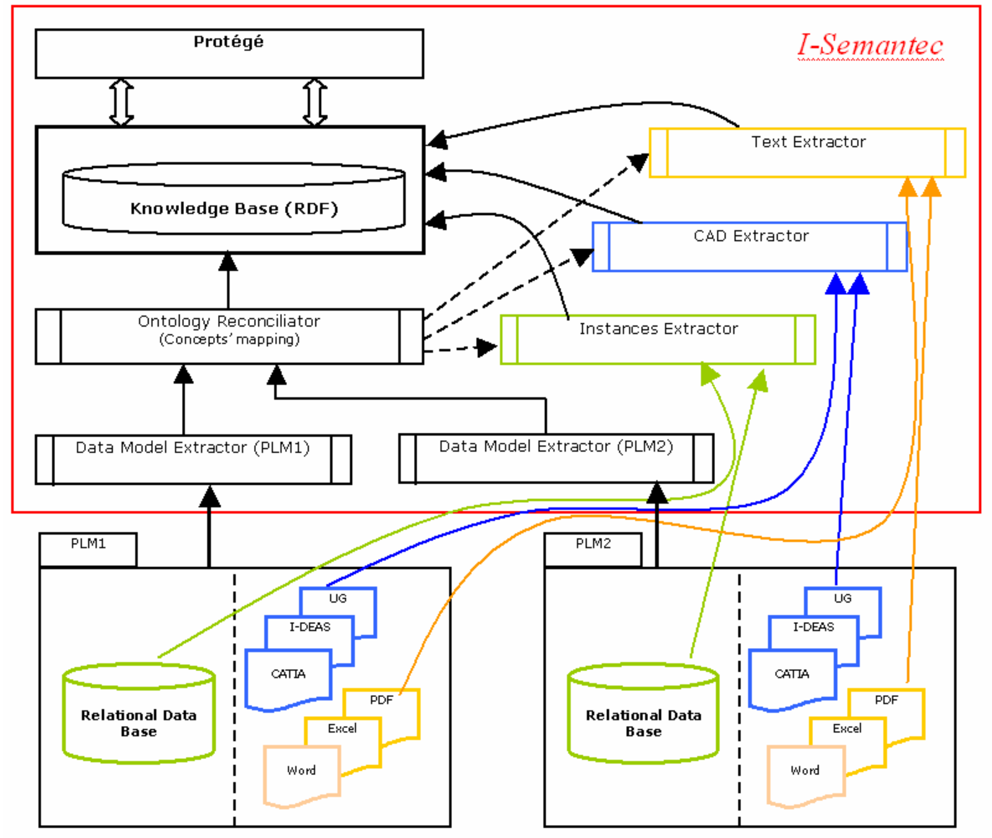

Figure 3: I-Semantec architecture

<u>Semantic modelling</u>

To formulate the ontologies and knowledge base, RDF, in its XML syntax, has been chosen because it more flexible to formulate the semantic. Thus, the use of RDF will enhance the interoperability among different systems and applications.

There exists tow levels of PLM data modelling. The meta-level, describing the data model with an ontology, and the instance level, representing instances of the data model, which are the content of the Knowledge Base.

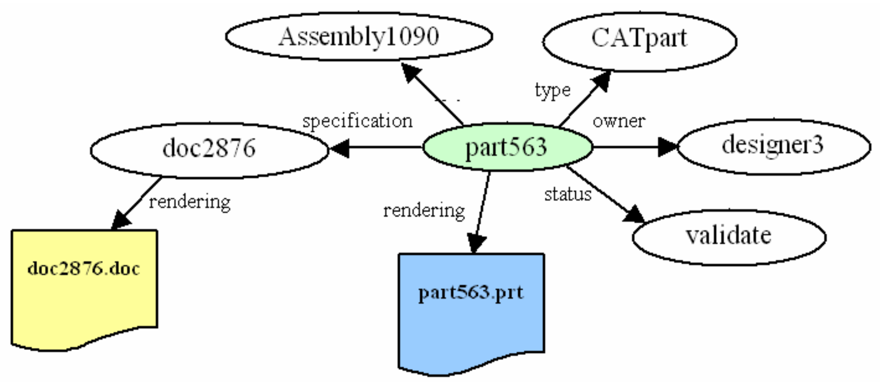

Figure 4: RDF graphical representation of product lifecycle related resources

RDF is a suitable language for the modelling of product lifecycle data because it can describe the relationships between all objects over the whole product lifecycle with a simple modelling approach [subject, predicate, object]. The example in *Figure 4* presents a *part object* (part563) with some related objects, such as owner, specification, status, etc. The graphical modelling can be written in triplet format in this way: [part563, is created by, designer3], [doc2876, status, validate], [part563, is specification by, doc2876], etc. RDF uses the uniform resources identifier (URI) for resources identification that what make easy to address the whole resources related to the product lifecycle.

Semantic extractors

The goal for the extraction phase is to reorganize (formalize) knowledge related to the product for enabling a better re-use.

The type of information that can be extracted from PLM may be 3D CAD model, 2D drawings, bill of materials (BOM), test and quality data related to specific product, manufacturing, assembly, or part details. In the preliminary version of I-Semantec only the metadata structure (data model) and content (instances of the model) are extracted. The principle of the extraction is to use a specialized API to reach PLM content. The extraction can be extended to several PLM from the same company or its partners. In such a context, the diversity of the PLM and their data model requires the implementation of specific extractors (an extractor by PLM systems and version to extract the exact semantics: properties and relations).

Thus, metadata will be formalized in RDF modeling language. This phase of formalizing consists in specifying the data models by an ontology defined in RDF and their instances by a set of RDF resources structuring the knowledge base.

Models combiner

A data model represents a set of concepts with detailed attributes (properties and relations). Data models extracted from various PLM systems are seldom similar. In order to merge these models, the module ontologies combiner allows to define "mappings" between concepts. For this process PROMPT is used (Noy and Musen, 2003). PROMPT is a tool based on Protégé (Noy *et al.,* 2001) and it allows to manage several ontologies, to merge distinct ontologies, to create only one consistent ontology and to extract part of an ontology. This combiner intervenes after the formalizing stage of data model into RDF.

Connectors

Two principal functions of the connectors are: document access and data update.

The resources available in the Knowledge Base are linked with a semantic relations and point to the documents existing in PLM - these documents are not duplicated but remain managed with the original PLM. When a user need to access to the document, a connection will be created towards the PLM system for loading the document.

The combiner of the PLM data model does not intervene only once in the process of enrichment of the RDF base, because the data model of a PLM varies little in time. Naturally if the data model change, mapping process have to be updated. Then the metadata issuing from the PLM are updated frequently by using the mapping defined in combining stage.

User interface

Currently, Protégé is used to browse the Knowledge Base representing the content extracted from PLM systems. The Protégé has a simple interface to visualize an ontology with their instances. Thus, it allows to navigate easily in a data model and its instances. The interface does not offer specific functionalities to handle PLM extracted resources. An improvement of the interface is planed for the information search.

CONCLUSION

This paper has discussed a knowledge re-use approach based on the Semantic Web technologies enabling the processing PLM information through an extensible infrastructure, in collaborative product development.

Currently, I-Semantec is tested with tow different PLM systems (Smarteam from Dassault Systèmes and TeamCenter Engineering from UGS). Extraction and combining is done in a suitable way, but there exist some lack in the interface to manipulate all capabilities. Some difficulties are remained in the implementation of the *data update* and *document load* connectors.

It is planed to improve the use of metadata and documents. For the textual documents, full-text searching method is not enough, it is necessary to take into account the user profile and the metadata describing the context of the required object. The contents of this kind of documents will be browsed with NLP tools (Natural Language Processing). For CAD files it would be interesting to provide product data, for example, on the cartridges of drawings, the design history, the annotations, etc.

Last, a more prospective improvement would be the knowledge representation by semantic models, such as Hypertopic model, developing under the Socio-Semantic Web field (Cahier and Zacklad, 2004), to enhance the current RDF modelling. This approach will enable to reinforce indexing data for better results of the information search and for better data structuring in user interface.

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