A DESIGN ENVIRONMENT FOR PRODUCT KNOWLEDGE MANAGEMENT AND DATA EXCHANGE

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Abstract: This paper reports on a distributed design environment under development for product knowledge management and information exchange. The system is able to use the company's existing base of knowledge and to push the manufacturing knowledge higher up into the design chain to reduce the need for costly and time consuming reworks and engineering changes. The design environment uses a knowledge based system Protégé and enables data/knowledge exchange through International Standards for Product Model Exchange (ISO STEP) and the Resource Description Framework.

Key words: Design Knowledge Management, Product Data Management and Exchange, Distributed and Collaborative Design

1. INTRODUCTION

Effective evaluation of the design of products is essential for the reduction of overall product lifecycle costs and reducing the time spent on engineering changes. The technologies which enable enterprises to collaborate on designs with their supply chains and customers already exist in the commercial domain. These include Product Data Management (PDM) and Product Lifecycle Management (PLM) at the enterprise level, as well as task-level applications such as the new generation of collaborative Computer Aided Design (CAD) applications. To overcome one of the major hurdles faced by enterprises in sharing product data, the ISO Standard for the Exchange of Product Model Data (STEP) standard Application Protocols (AP) have been implemented by CAD vendors, and the World Wide Web Consortium (W3C) standard eXtensible Markup Language (XML) has been used as a format to exchange a range of textual information between business systems such as PDM/PLM and Enterprise Resource Planning (ERP).

However there are still many shortcomings not addressed by the range of applications currently available. The most important issues include interoperability between applications from different vendors without the need for specific interfaces and translators. The XML format which has been widely used for data exchange and is machine readable by any XML parser. However, readability alone does not create understanding of the meaning within the data. Vendors and academics have been relying on producing specific interfaces for different XML vocabularies, meaning that any heterogeneous engineering application will have difficulty retrieving and processing data in XML without lengthy and costly integration with all the data sources. On another note, the STEP standard(s) have also created some mixed results in industry. The AP-203 and 214 standards have been widely adapted by CAD vendors to generate geometric data, for configuration controlled geometric designs and automotive designs. However these Application Protocols don't provide the necessary machining feature information needed for process planning. To bridge the gap, AP-224 was created for representing machining features for process planning. The main problems that have dogged this effort has been the lack of effective automatic feature recognition to transform Boundary-Representation (B-Rep) geometry into machining primitive features such as bosses, holes and threads.

There have been a number of major studies and development efforts in concurrent product design within the supply chain and extended enterprise domains. For example Sanchez et al [1997] developed a knowledge based system (KBS) for the integration of manufacturability issues into the conceptual design phase of a project. Brunetti and Golob [2000] developed a design-by-features tool intended for use as at the conceptual stage of development. The software captures conceptual design intent (requirements), functions, product structure, assemblies, and individual components with explicitly declared features. Shyamsundar and Gadh [2001] developed cPAD (collaborative Product Assembly Design System). It is an internet based tool for the collaborative assembly design of mechanical assemblies and constraints between the Original Equipment Manufacturers and their supply chains. Zha and Du [2001] have proposed a STEP based application to manage the entire product lifecycle using various STEP APs to define the product geometry, assembly and meta-data. The information that is not already defined in a STEP-AP is modelled in Express. Various other research efforts in Feature recognition technologies have been made by Shah [1999], Bhandrakar et al [2000].

Efforts have been made to solve the problems of analysing conceptual designs and reusing the generated designs in the embodiment design and manufacturing phases of the project. Feng and Song [2000] developed a conceptual design activity model to describe the activities in the conceptual design phase. An object model in Unified Modelling Language (UML) was devised to embody this. Rudolph [2000] tried to solve the problem of managing engineering data by creating an XML vocabulary to embody all the engineering terms in use, however problems would arise because of a number of factors: Engineering companies have different ideas of what defines their design data, and the XML vocabulary can be read only by systems already programmed to receive it and interpreted by a user or application familiar with the vocabulary. Lihui [2002] has a review of current and near-future conceptual collaborative design applications.

The open-source software community, Open-Source Developer-Network [2002] has a number of applications such as Open-source PDM TUTOS (as a backend server), open-cascade (solid modeller) and Protégé-2000 (graphical knowledge based system) which can be used as components within a collaborative conceptual design environment.

2. RESEARCH APPROACH

This study has focused on the experiences of automotive and discrete machining companies in integrating their product realisation cycles with their supply chains and their customers in real-time, and also to enable the company to make rapid appraisal and cost-estimation for their customers from simple concept designs.

This embodies the transformation of the concept design into analysable forms for Computer Aided Process Planning (CAPP) systems. In addition the system has to be able to reuse the company's existing base of knowledge and to push the manufacturing knowledge higher up into the design chain to reduce the need for costly and time consuming reworks and engineering changes. Initially a PDM/PLM application server was used to test the basis of currently available systems for managing product data and product data flow in a development cycle. An example project's data was evaluated and workflows created along the development process of the company.

Concentrating on the areas of knowledge capture and reuse, design creation and evaluation, and concurrent working environment, it was apparent that the real problems were not in communications technologies but in the correct management of knowledge and the decomposition of knowledge “nuggets” into separate objects.

The Resource Description Framework (RDF) has been used in this application, as opposed to XML. The reasons for this choice are the extra flexibility and “machine-understandable” format of RDF graph-node model as opposed to the simple “machine-readable” XML based mark-up vocabularies. In effect, any heterogeneous system can parse the text in the RDF document and be able to derive the semantics and context from the Universal Resource Identifier (URI) and metadata attached to every entity. RDF has been modelled in this instance using the Protégé-2000 KBS system and visualisation was made with OntoViz. The KBS was integrated with the Windchill PDM system using Protégé’s Java-2 API and the RDF knowledge bases stored in a Windchill cabinet as separate objects as opposed to a single document. This allows the knowledge to be shared, modified and automatically creates an audit trail within the PDM system. The other component used an AP-224 based automatic process planner to generate plans from concept designs. For the sake of flexibility any geometric design in AP-203 can be used as a basis on which feature information can be added. For the feature information, the AP-224 standard was modelled into a CLIPS based expert system, allowing valid AP-224 models to be created using the same knowledge base system as used for the company’s “non-geometric” data. Furthermore a plug-in written for Protégé-2000 allows for the mixing of feature and meta-data information in the knowledge base, meaning that users can access the information stored in STEP models from knowledge queries or other RDF enabled parsers. This integration at low level between the geometric, feature and “meta-data” within a single environment is intended to reduce repetition, errors and also enable the reuse of all the data created during the conceptual design process. Once an AP-224 model has been created the LOCAM CAPP tool generates a machining process plan on the fly.

3. SYSTEM IMPLEMENTATION

An example project has been evaluated and workflows created for the development process of the collaborating company. The 4-layer architecture (Figure 1) below illustrates the tested system using open-source software components. The open-source application has been deployed alongside the commercial PTC Windchill PDM system to test their relative merits.

In the application the bottom layer consists of the database, this can be chosen from the range of SQL92 compliant databases available, and for this test-case MySQL was utilised due to its stability, ease of use and close integration with the PHP scripting language that the open-source PDM was written in. On top of this lay the two open source gateways, one is Apache web server for serving HTML and PHP based web pages and the second is the Tomcat Servlet engine which serves the Java Server Pages (JSP) based applications and the Enterprise Java Beans. These three layers (database, web server and application server) form the server side of the system.

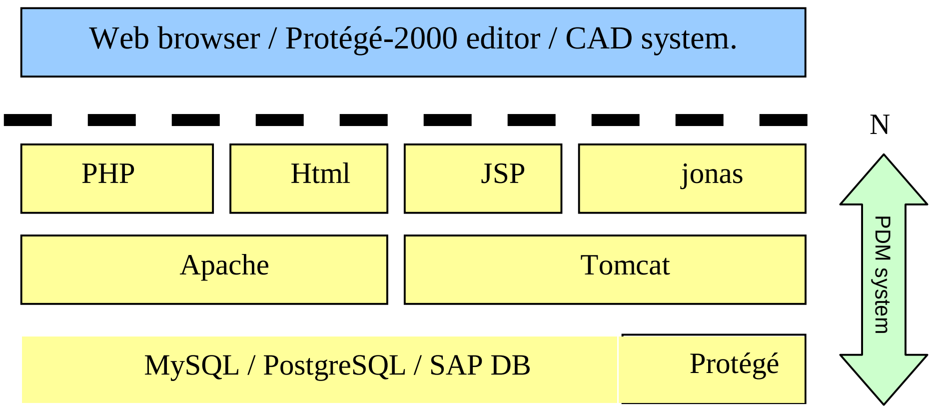

Figure 1. Open Source server

The dashed line in Figure 1 denotes the network connection, the connection is TCP/IP for both Local and Wide area networks (as pre-determined by the use of Apache and Tomcat web-servers).

On the client side, the user has three main items. First of all the web browser through which interactions with the PDM system are carried out, secondly the Protégé Java applet that allows the user to query and manage the knowledge base and finally a CAD system to enable the user to create and manipulate the STEP based models held in the PDM system. This user interface ensures ease of use for the user because the web-browser and their own CAD system are already familiar to the user with the only “new” tool for interaction being Protégé. Protégé has a fully graphical user interface with drop-down multiple choice lists and highlighting of errors in information entered by the user, in addition it uses the SWING package to maintain a consistent user interface across all platforms (Windows, Unix, Linux).

Windchill is an out-of-the-box solution for product data management and lifecycle management. It has a very similar architecture to the open source systems and even relies on open-source technology for some of its key components. The system uses apache and tomcat web-servers, Lightweight Directory Access Protocol (LDAP) server for managing user information and platform independent Java for its core functionality. It does however use one major commercial application for its database (Oracle 8i). The system has however got a number of shortcomings. It is a traditional document management tool, whilst it can store all manner of data and make revision controls, it does not however have an intelligent method of containing and persisting information in an object oriented format. To alleviate this, the functionality of the system was extended to include the management of knowledge objects from Protégé. This extension also includes the management of STEP geometric entity knowledge within the PDM system in an intelligent and object oriented manner (Using the open-source IFC model server logic). Knowledge is stored as objects within the modified PDM system, and the STEP models and geometry are managed by an Open-Source application developed at the [Technical Research Centre of Finland, 2002] called IFC-Model server. This server manages STEP entities as distinct objects within an object relational database. This was integrated with the lifecycle management and workflow functions offered by the PDM system, enabling the management of Industry Standard STEP models in a knowledge-centric manner.

The resulting system is the evolution of product development management systems from document centric PDM systems to knowledge centric, intelligent systems of the future [Aziz et al., 2002; Cheung et al., 2002; Gao et al., 2002]. (Figure 2) illustrates this working methodology. In this diagram the differences in the format for storing knowledge are illustrated. In the traditional PDM system word processor documents and some excel worksheets contain the company’s knowledge assets and these are stored on the server with some “meta-tags” to identify the basic purpose of the file. The same is true for the storage of the geometric models within the system, as each CAD file is stored with some tag information. In the new application, individual items of information are stored as separate objects and tied together with the Universal Resource Identifiers of the RDF standard. This enables the system to create reports that mimic the “layout” of static documents but rely on a single source of up- to-date knowledge, eliminating duplication, and enabling the user to modify sub components and assemblies of geometric models without retrieving the complete model (reducing network bandwidth usage).

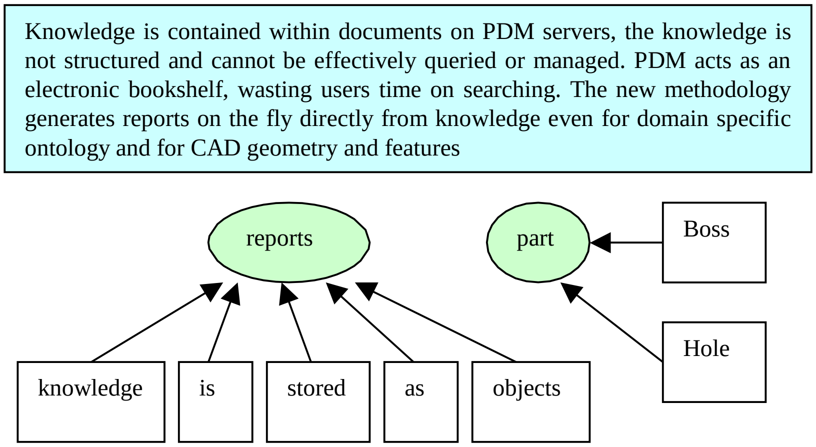

Figure 2. Knowledge centric product data management

Persistence of the models is within the Oracle database (for Windchill) and in MySQL for the open-source solution.

4. EXAMPLE

The company specific ontology was captured by the knowledge engineering team using a number of methods including, capturing and decomposing documents from the company repository and extracting the entities that define the root knowledge within the documents. The rules and regulations covering design decisions, and project management workflows and procedures were captured using two-way interviews with domain experts. These were written into protégé producing the RDF schema, a small section of which can be seen below (Figure 3). The schema contains the company's information that had been previously held in word documents, excel spreadsheets and some access databases. This new methodology has eliminated knowledge versioning problems, generation of reports and enabled the reuse of knowledge once its been entered into the system.

The resulting ontology has been normalised and as far as possible combined with elements from the STEP standard to create a generic ontology for design knowledge, that can be extended by the user or project manager for domain specific tasks. Figure 3- shows a small section of a steel bridge panel customised ontology. The workflows to manage the product design process are also defined and stored within the Design Knowledge Management system.

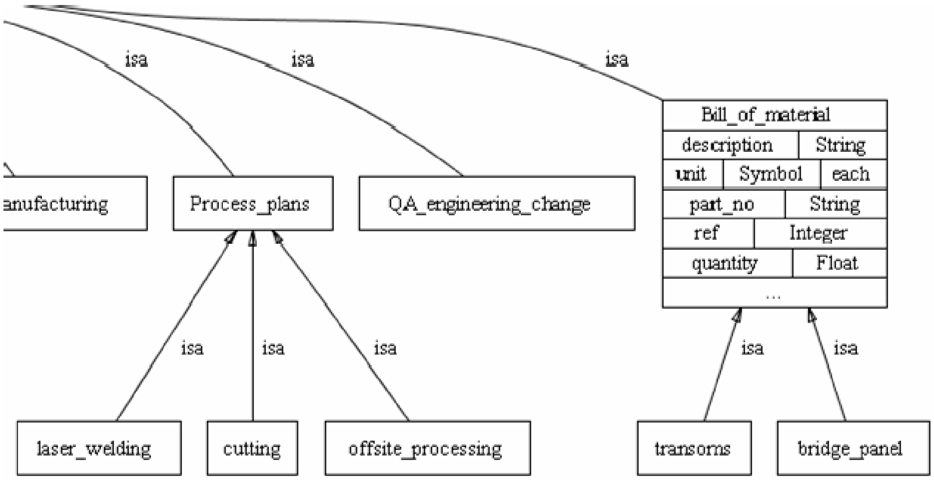

Figure 3. Hierarchy within ontology

Figure 4 illustrates an example workflow which has been generated in XML Process Definition Language (XPDL) of the Workflow Management Coalition [2002]. It is used to control the activity, gate control within the concept development process of a company. Due to the definition of XPDL in XML, it has been possible to integrate the workflow standard within the overall design ontology in RDF enabling every item of knowledge relating to a design or project to be cross referenced to the project it is attached to by default.

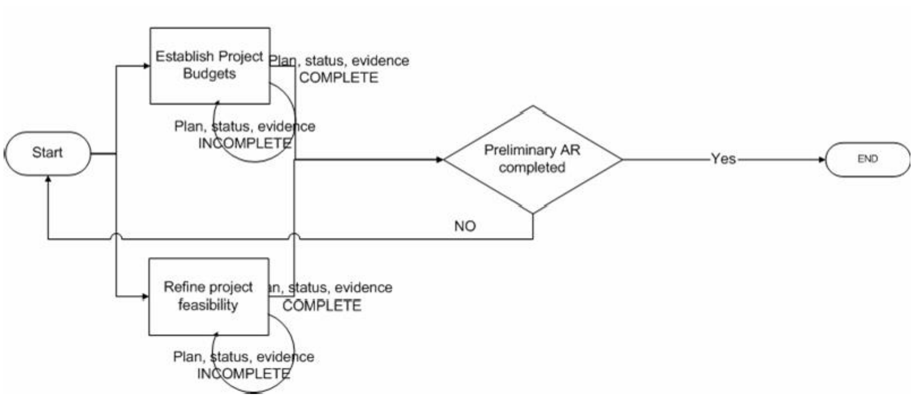

Figure 4. Workflow process, visualized from XPDL

The STEP AP-224 feature models are defined in the Protégé System as "extended-CLIPS" and use the Java Expert System Shell to define the rules and functions of the standard. In addition some of the rules have been created using the Protégé Axiom Language (PAL) and the constraints these impose enable error-checking for the user during the definition of features. Due to the size of the standard, only a subset of AP-224 and STEP-PDM has been translated from their original EXPRESS schemas.

5. CONCLUSIONS

The system in development is proving intuitive to use and flexible in the data it can store and process, the application of disparate software components held together by a PDM system for data persistence and flow and by a flexible RDF based knowledge base has enabled the creation of mixed geometry-knowledge models to be created. Even though such techniques have been tried in the past the unique flexibility of using RDF format for modelling and persistence has opened up the possibilities for sharing, creating and analysing such meta-data and topological features in a way that required proprietary application servers and specific "plug-ins" in the past with STEP Part-21 and XML based solutions. In addition the methodology in itself is application independent and any RDF capable editor and STEP compliant CAD system can be used to work concurrently, enabling users to move away from feature-rich but closed proprietary systems. The knowledge-centric approach to managing the enterprise knowledge enables a quantum leap in flexibility in terms of structured knowledge creation, query, re-use and dissemination, as well as the advantages offered for lifecycle and versioning over previous PDM approaches by ensuring that the versioning and lifecycle states are attached to items of knowledge as opposed to documents [Aziz et al., 2003; Cheung et al., 2003] (which contain the knowledge, and may be inaccurate, duplicated and unstructured).

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