THE APPLICATION OF WEB-BASED TECHNOLOGIES IN PRODUCT DATA MANAGEMENT AND MANUFACTURING SYSTEMS INTEROPERABILITY AND DATA EXCHANGE

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KEYWORDS

XML, XMI/Stream, UML, PDM, Manufacturing Systems.

ABSTRACT

As the use of web-centric technology matures within the current market, one of the most widely used standardized data exchange formats is XML (Extensible Markup Language). This is due to the fact that XML-wrapped data can be used and understood by any application that is XML-enabled. This is one of the main factors this paper aims to exploit in order to tackle the problem of improving manufacturing product development in a distributed and collaborative environment within the World-Wide-Web. The objective of this paper is to investigate how XML and the proposed standard XMI (XML Metadata Interchange) can be used as the mediation for associating a commercially available Product Data Management (PDM) system and a manufacturing system, which consists of manufacturing and design domains. In particular, the focus of this paper is to emphasise the way in which systems interoperate and deliver data solutions to enterprise information challenges.

INTRODUCTION

Nowadays, the majority of engineering and manufacturing companies have most likely invested in Computer-Aided Design (CAD), Computer-Aided Engineering analysis (CAE), and Computer Aided Manufacturing (CAM) software tools to aid the product development activities. In general, the purpose of procured tools is to enhance the tasks within the respective disciplines of design, analysis, and manufacturing. Industry has benefited from improved quality, lower cycle times, and reduced costs in each discipline. However, little progress has been made to enable information to be effectively managed or communicated from discipline to discipline, and this is a requirement to realize the expected cost, schedule, and quality benefits.

One of the problems is the lack of use of modern technologies in early design and manufacturing phases and also the effective information distribution to support product development activities (Cheung et al., 2000). Examples of these activities include manufacturing process planning, workflow analysis, knowledge management, product design and process modelling. It has been claimed that conceptual design has an impact of over 70% of the life-cycle cost of a product and, 70% of the time being wasted on searching for information during product development stages (Welsh et al. 2000), (Ni and Lu. 2002). Additionally, manufacturing processes display ever growing complex and dynamic behaviours due to increasing product complexity and distributed and collaborative engineering demands. It is therefore, the issues on the application of the web-based technology of XML and XMI that must be addressed in order to ease the obstacles on system interoperability and data exchange. A conceptual architecture is introduced as a means of bridging the gap between the application of PDM and the Manufacturing and Design Domains for the benefit of collaborative work teams. Such technologies will enable work teams to interface and develop, review, analyse and reuse design and manufacturing knowledge and information/data modelling within a manufacturing enterprise

USES OF WEB-BASED TECHNOLOGIES AND DISPARATE TOOLS

The research described herein is presented as part of a collaborative project between the University of Durham, Cranfield University and industrial partners. The software tools used to explore the feasibility of operational improvement are the utilisation of web-centric supporting technologies (such as XML and XMI), the Unified Modelling Language (UML), Java Programming Language, the CAPABLE System and a state-of-the-art PDM system. The CAPABLE system is based upon the CAPABLE Aggregate Process Planning System developed by the Design and Manufacturing Research Group, Durham University. The PDM software is of the proprietary system Windchill.

Application of XML

XML is the universal format for structured documents and data on the World-Wide-Web. It is a Meta model for data exchange supported by major industry rivals including IBM, Microsoft, Oracle and Sun. It is an open standard, platform independent, license free, vendor neutral and is strongly supported throughout the Internet. XML also allows the developer to freely describe structured and unstructured data and their relationships (Widergreen et al. 1999). There are several other benefits and features such as acting as a mediator for accessing many forms of data. Thus, it can be used to mediate structured and unstructured data on the Internet due to its flexibility to support integration between disparate data sources (Lowery. 2001).

XML allows automatic enforcing of semantic constraints (Duboz. 2002). Furthermore, XML is simple to implement and very powerful at describing entities. The XML specification describes XML *documents*; a class of data objects stored in computers, and partially describes the behaviour of XML processor programs used to read such documents as well as provides access to their content and structure. XML documents are composed of *entities*, which are storage units containing text and/or binary data (Connolly 1998). Text is composed of character streams that form both the document character data and the document markup. *Markup* describes the document's storage layout and logical structure. A well-formed XML document is unambiguous, so that a browser or editor can read the tags and creates a tree of the hierarchical structure without having to read its Document Type Definition (DTD) (W3C. 2002).

There are many applications that use XML in the research community, for example, the database interoperability (Bouneffa. 2001), the integration of applications (Xu and Degoulet. 2001) and (Villa. 2001), the use of XML for Integrating Modeling Architecture (IMA) framework through the use of Document Type Definition (DTD). XML is becoming widely used for representing both the process and the content information when deploying models. Process information includes the messaging infrastructure and workflow control that guides the process execution (Carlson D. 2001). While XML is a good way to share data, for this project, something more is needed to share the object built in the Manufacturing System, which is defined in UML. Hence, a new standard XMI (XML Metadata Interchange format) from the Object Management Group (OMG. 2002) is used for sharing objects using XML.

An Introduction to XMI

The intention of XMI (XML Metadata Interchange) is to propose a way to standardize Extensible Markup Language (XML) for users to exchange information about Metadata based on the following points:

- Information about what a set of data consists of
- How it is organized, and
- How any set of metadata is described so that users across many industries and operating environments can see the data in the same way.

Furthermore, XMI is intended to help users and developers using Unified Modelling Language (UML) with different languages and development tools and the semantically rich Meta Object Facility (MOF) to exchange data models and sharing complex information (Cheung et al., 2002; OMG. 2002), (Dirckze. 2000). XML bridges part of that gap by providing the building blocks for "serializing" UML data textually. However, XMI will be the driving force for a more powerful solution by capturing and expressing the relationships defined by UML (Laird. 2001).

One application by Anagnostaki et al. 2000, describes an effort to create a common document-oriented architecture for the interchange of medical data in health care telemedicine applications. This particular research utilized XMI to provide the meta-model, which specified an open information interchange for object-oriented models and data using XML. The XMI specification in this case integrates XML with UML and MOF specifications by providing a standard way to convert objects into XML. The author’s inspiration to apply the relevant technologies into engineering applications is based on this effort.

XMI Eases the Problem of Systems Interoperability

In reality the applications of the different tools used in this research makes it very difficult to achieve the objective of interoperability due to the fact that the software tools often cannot easily interchange the information used with each other. One of the obstacles is due to the difficulty of understanding the semantic used in individual applications. However, according to (OMG. 2002), the application of XMI can ease this problem by:

- Providing a flexible and easily parsed information interchange format. In principle, a tool needs only to be able to save and load the data it uses in XMI format in order to interoperate with other XMI capable tools. There is no need to implement a separate export and import utility for every combination of tools that exchange data.

- The makeup of an XMI stream is important too. XMI is intended to be a "stream" format. That is, it can either be stored in a traditional file system or streamed across the Internet from a database or repository. As illustrated in Figure 1, it contains the definitions of the information being transferred as well as the information itself. Including the semantics of the information in the stream enables a tool reading the stream to better interpret the information content.

- A second advantage of including the definitions in the stream is that the scope of information that can be transferred is not fixed; it can be extended with new definitions as more tools are integrated to exchange information.

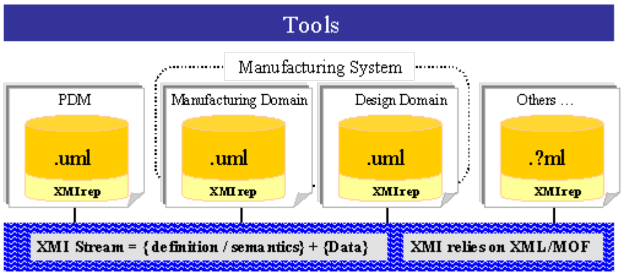

Figure 1: XMI Stream in PDM and Manufacturing Systems Interoperability

The Manufacturing System

The manufacturing system consists of a Manufacturing Domain and a Design Domain. The Design Domain is under development at Cranfield University. As for the Manufacturing Domain is being developed at the University of Durham and consists of the CAPABLE Aggregate Process Planning system and commercial software tools which will be briefly introduced at a later section.

The CAPABLE system is used to generate preliminary process plans (Bramall et al. 2001). The infrastructure of the CAPABLE system is shown in Figure 2, which illustrates the main components in a UML representation. CAPABLEObject is the highest level of the system, which supports all major data models such as resource, process, process planning, product models and knowledge based system. In addition, CAPABLEObject uses Serialisation to identify the type of object that is being dealt with and holds the path of the directory where objects of this type should be stored in the databases. However, in order to use it more effectively the output of the results (or the objects) must be XML-enabled so that it can be used to integrate with disparate systems and Internet technologies using XMI Streaming in order to distribute information in a collaborative environment.

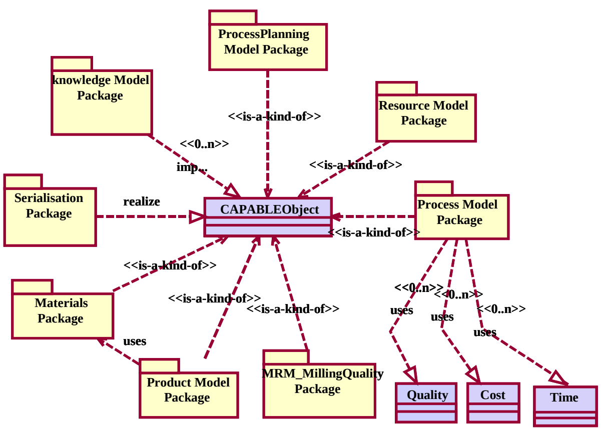

Figure 2: CAPABLE System in UML Representation

Windchill PDM System

PTC's Windchill PDM system provides a Web-based environment for the creation, management, and evolution of product and process information. Its core capabilities enable users to collaboratively develop and share data in a controlled environment. The system itself encompasses various functionalities, the functions which are specifically applicable for this project are introduced as follows (PTC Windchill, 2001):

- *LifeCycles*

LifeCycles are interactive objects that require check-out and check-in for modifications, hence, enabling the user to create, update, view and changes as well as to define the state of each task.

- *Workflows*

Workflow processes determine what happens within each task and also facilitates delegation of tasks to specific members within the team as well as adding their own "mark-ups".

- *Version Controls*

This offers Version control for the design and the ability to see the history or "evolution" of a design through all its iterations.

- *Visualization*

This allows different types of product-related information to be viewed throughout the enterprise as well as the ability to interrogate and 'markup' CAD formatted files and on-line conceptual reviews.

- *Windchill Cabinet*

The Windchill Cabinet helps by storing information in a cabinet and folder hierarchy i.e. displaying information from general to specific topics and providing methods of locating information appropriately.

- *Customisation factor*

This includes object-oriented software development tools such as Java and Unified Modelling Language (UML).

THE INTEGRATION 'WRAPPER'

This is the proposed architecture, as illustrated in Figure 3, which consists of different components used in this research. The deployment of the Windchill PDM provides an 'integration wrapper' for the entire integrated system. It supports an online distributed and collaborative environment with specific functions including product data/document management, version control, workflows and lifecycle management. The term 'wrapper' means wrap different data into a common format i.e. XML. An Oracle database server is employed to handle requests, knowledge and model information as well as deploy Windchill PDM functionalities through the use of Java Database Connectivity (JDBC).

The main interfacing mechanism of the Windchill PDM is managed by running a Windchill Applet with a servlet to support a Manufacturing System so that it can

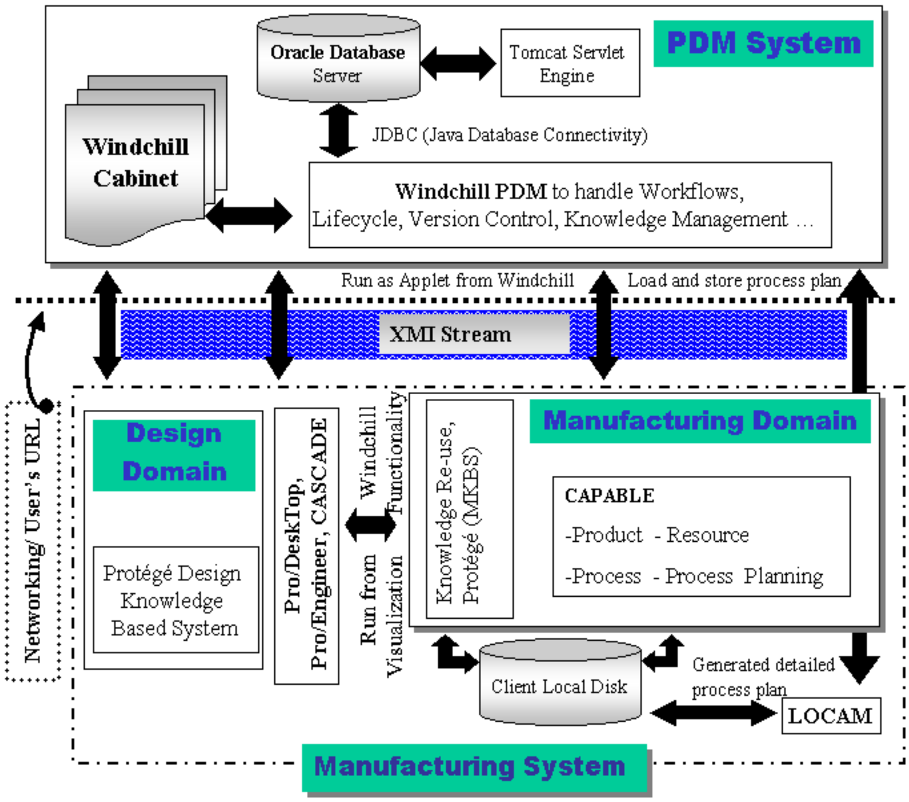

Figure 3: The PDM Integration Wrapper

communicate with CAPABLE Process Planning. Tomcat [1] deploys as a servlet container in conjunction with a Web server, such as Apache [2] to support Java based and XML implementations. XMI is being deployed as the interfacing media between PDM and the Manufacturing System for data interchange i.e. the XMI Stream. This recommendation enables interchanging portions of XML documents while retaining the ability to parse them correctly and, as far as practically concerned, it can be formatted, edited, and processed in useful ways. More importantly, as described previously, the deployment of XMI enables interchange with object-oriented models such as the CAPABLE Process Planning Engine, PDM Workflow analysis and data using XML for capturing and expressing the *relationships* that UML expresses.

There are two other pieces of third party software that will be deployed within the research including CAD systems (Pro/Engineer, Pro/Desktop and Open Cascade Solid Modeller) as well as LOCAM (a manufacturing planning system). All CAD systems are being used as solid modellers to display the image of the product through the Windchill Visualization functionality. LOCAM is used to generate process plans at the final stages of product design and development. In addition, it has the ability to take STEP AP224 files generated by the Product Model and outputs XML formatted process plans through the Windchill PDM.

A TYPICAL SCENARIO IN A TIME-BASED DEPENDENCY

Figure 4 depicts the interactions of product design and process planning activities supported by a PDM system in a time-based dependency scenario. The principle of the illustration shows a customer product requirement as it reaches the conceptual design stage at the Design Domain. As a result, a new product definition is being generated and delivered to the Windchill PDM Cabinet for updating the product requirements. By associating the requirements with the new design knowledge, a redesign may be requested at this stage. Subsequently, an updated product definition will be generated in the Design Domain, at the Enterprise Resource Update level within the PDM. The newer versions of the product definition and resource requirements are again updated and transferred to the Manufacturing Domain, i.e. this results in a 'mirror image' of information to be sent to the Manufacturing Domain through the XMI Stream.

It is at this stage that the CAPABLE Aggregate Planning Engine is used to generate a process plan. The Process Planning Engine (PPE) within the CAPABLE System captures the information of this output. The new process plan is then being delivered through the XMI Stream to the PDM system for Plan/Review, and subsequently is being readied for release. The application of XMI and XML in this scenario improves the quality of both design and

[1] **Tomcat** is the official Reference Implementation for the Java Servlet and JavaServer Pages technologies.

[2] **Apache** is a public-domain open source Web server.

More information can be found on: *http://jakarta.apache.org/*

production decisions. In addition, the efficient management of product and process knowledge from the early stages of design should result in the reduction of product development lead times and an increase in production efficiency.

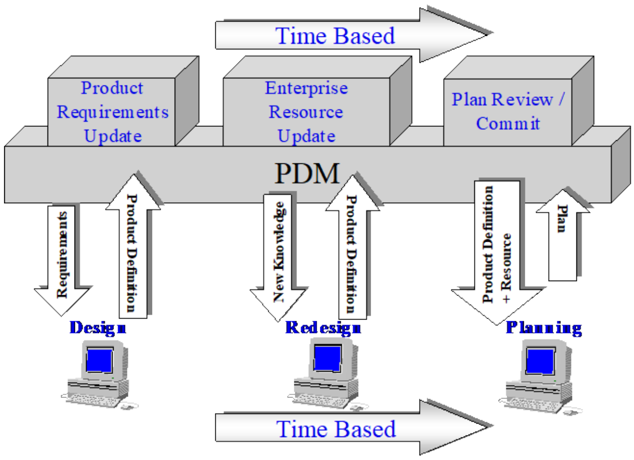

Figure 4: A Typical Scenario in a time-based dependency

CONCLUSIONS AND FUTURE PRESPECTIVE

This paper has outlined the links between PDM and Manufacturing System by utilizing advanced web-based technologies. The significance of using XML and XMI Stream to support systems interoperability and data exchange has also been highlighted. It is necessary to identify the data being used as input and output in every model in order to make an XML representation of them. This representation permits the comparison of data at the semantic level for model connection in a very simple way. Subsequently, an example of mapping UML to XML by using the OMG XMI standard will be implemented as the project progresses. This is particularly important in that it will prove and demonstrate the ability of handling distributed and collaborative product development information exchange by using the proposed tools.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of the Engineering and Physical Sciences Research Council (EPSRC) and the industrial collaborators ArvinMeritor, LSC Group, Mabey & Johnson and PTC. This paper is presented as part of the Distributed and Collaborative Product Development and Manufacturing Knowledge Management research project funded by EPSRC, Grant GR/R26757.

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