Advanced Tools and Technologies for Collaborative Product Development and Knowledge Management

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ABSTRACT

The shortcomings of the current state-of-the-art in distributed / collaborative product development of engineering products from concept to production are: A lack of an integrated interface for the full spectrum of functions needed by complex conceptual design for manufacture and assembly; and management and re-use of concept design knowledge within an integrated design environment. Recommendations are given on the integration of these disparate technologies for the benefit of collaborative work teams to enable them to use a seamlessly integrated interface to develop, review, analyse and reuse engineering and manufacturing knowledge and models within the enterprise and the supply chain. A proposed methodology and a functional description of such a system is presented. The system utilises the Protégé-2000 expert system on top of the Windchill data management / collaboration software. International Standard for the Exchange of Product model data – STEP is to be used for machining feature definition.

Key: CPD, STEP, Conceptual Design

1 INTRODUCTION

In engineering product development there is a lack of clearly defined knowledge and product data flow within the initial stages of the product development process. The problems of acquiring and correctly translating customer requirements into concept designs that can be analysed for manufacturability before committing to a full detailed design have not been fully solved. There exists a clear detachment between customer requirements, engineering design and manufacturing roles within the development process and only manual solutions have been used to bridge the disciplinary gap. The primary problems with this solution, as well as Product Data Management (PDM) and Collaborative Product Development (CPD) technologies are the lack of knowledge management facilities and collaborative design and manufacturing analysis tools. The other disadvantages associated with traditional concurrent engineering are co-location, inability to re-use expertise and delays in assessment of concepts.

To some extent these problems were tackled by software solutions such as Collaborative Product Development (CPD) programs. However there are a number of issues that these software solutions do not yet tackle. Hsu (1) discussed the problems faced by designers and manufacturing engineers at the conceptual design stage of engineering projects and highlighted a number of areas of research where computerisation of the conceptual design stage would allow for the creation and selection of best designs for embodiment design. The areas of research highlighted include sketch based entry of 2D geometry into fuzzy kbs, use of graph theory to represent product and the relationships between its components, and the representation of the concept as design as identifiable manufacturing features.

The UK Engineering and Physical Sciences Research Council (EPSRC) has initiated a 3 year project in conjunction with Cranfield and Durham universities, engineering software vendors LSC group and PTC corporation, and the industrial companies ArvinMeritor and Mabey&Johnson. The project aims to develop a methodology and software tools to help engineering companies improve their conceptual design processes, the storage and re-use of design knowledge and the effective manufacturability analysis of the concepts in a distributed and collaborative environment.

2 CURRENT TECHNOLOGIES

Song (2) tackles the problems of integrating CAD and CAPP systems and generating concept designs that can be analysed at an early stage for manufacturability. The authors highlight the problems of modelling conceptual model ideas and transforming those imprecise ideas into analysable meta-data and geometry. The authors developed a conceptual design activity model to describe the activities in the conceptual design phase. Then an object model (in UML) was devised to embody this. However the author does not take into account a number of other factors considered in the current EPSRC project including customer requirements knowledge or integration within a collaborative environment. Today there are a very wide array of tools available to enable collaborative development in multi-disciplinary teams that may be geographically separated. In order for this to take effect a number of elements must be in place. Bi-directional communications between all team members both for the exchange of comments and the ability to view current design on a shared “whiteboard”. The ability to manage workflows and delegate tasks to specific members within the team. The ability of all team members to comment on the design and add their own “mark-ups”. Version controls for the design and the ability to see the history or “evolution” of a design through all its iterations. The ability to share design expertise within the team enabling persons from other disciplines to make use of “reusable” expertise without consulting directly with the expert. The ability to update and modify the “meta-data” and rules according to the project requirements and the evolving state of technology. The capability to take the best path for the design from the earliest concept, which is where the potential future success or failure of the project is cast.

The building blocks of such a collaborative development environment consist of: Product Data Management environment, which holds all design data and meta-data as well as enabling version control of design iterations and access to shared work areas “whiteboards” for the team members. Computer Aided Design environment to generate the conceptual designs and allowing the visualisation of product design for non-technical members and for design evaluation (DFMA). Viewer technologies to allow real-time collaboration of geographically disparate groups, allowing them the ability to mark-up designs and recommend changes. Interface between the CAD software and Process Planning software in order to assess the potential manufacturability of a design from the conceptual phase. Interface with Resource Planning tools in order to forecast the potential costs of the design from an early stage of the project. The ability to easily create, modify and utilise expert knowledge during the early design phase. The ability to pass the conceptual design as a "rough sketch" directly into the CAD tool for detailed design. To create assembly plans for the components and evaluate the potential viability using assembly planning tools.

Shyamsudar (3) have developed a tool over the called cPAD (collaborative Product Assembly Design System). It is an internet based tool for the collaborative assembly design of mechanical assemblies and constraints. The system uses a three tier architecture for the information model with an ASP (application server) and middle-tier Intelligent server written in java to control the communication between client and ASPs. The software has a web server (apache), parasolid based kernel for solid models (in C++), an MS access database and catalogue servers with JDBC interface. Finally there is a visualisation server which converts the parasolid model into a compact geometry model. However there is no provision to enable collaborative working in real-time, or to generate STEP compatible outputs for later processing. The lack of version control and integration with PDM application is another shortcoming, that can be overcome. The system has great potential, however the inclusion of machining feature abilities (and mapping those features onto STEP AP224 files), as well as mapping the assembly information onto AP203 or AP214 assembly data would be a good course of development.
Kim Et al (4) Have developed a "Distributed open-intelligent PDM". The philosophy behind this particular PDM implementation is the use of open-standard only tools and file formats. The PDM system contains all the software tools contained in other PDM applications such as PTC Windchill, however there are a number of features currently unique to this implementation (at least it does not come as standard on other PDM applications). The use of intelligent agents to perform many of the PDM tasks and KQML for queries sets it apart from other PDM implementations. The PDM software implements a dynamic and flexible workflow model, as opposed to the rigid workflows seen in many commercial PDM applications, this greatly enhances the flexibility and therefore usability of the system in a real-world situation, where rigid workflows are considered to be a nuisance. In addition, the program is designed from the outset for the use of STEP based model files to store and distribute product information. SDAI (Step Data Access Interface) is used for content searching of Product data. However, no mention is made about which AP of STEP they are intending to use.

A number of stand-alone and networked conceptual design tools are available. All the tools have the ability to generate solid models, but achieve their aims with different approaches. ICAD, AML and TIE use a fully parameterised expert system to hard-code the model without any graphical editing. The more orthodox approach creates geometry interactively such as Pro/Desktop or SINFONIA and CATIA knowledgeware occupies the middle-ground with a mixed AI and geometry approach. A new category of tools aims to combine the project management, collaboration and data-sharing features of CPD applications with concurrent online CAD design. One program AML is simply a web-enabled form of ICAD (expert system based parametric design), whilst others such as Syco3D are experimental LAN based solid modellers. Fully commercialised products offering distributed design capabilities exist in the form of ImpactXoft IX SpeeD and Alibre Design, whilst some limited capabilities for model creation and editing are available in CoCreate's OneSpace program.

These programs take the functionality of the programs one stage closer to fully distributed design for manufacture; however they are still missing the vital features of manufacturability analysis and preliminary process plan generation for the concept. Also some progress is being made to enable customers to clearly define their needs through the use of such portals as the online automotive tendering service www.covisint.com and through portals such as PTC's DynamicDesignLink add-on to its Windchill collaborative product design tool.

3 PRODUCT DEVELOPMENT EXAMPLE

For the proposed software methodology to be tested, the software has to be configured to support a particular engineering product family. In this instance latch assemblies for the automotive industry were utilised as the example. The workflow and development methods used by the manufacturer, and the interaction between them and the customer (OEM) and supply chain were collected. The information collected falls into a number of categories including: Workflows to define the tasks and sequences in the development project. Gate-reviews, which include the necessary verification of the manufacturability and, in the case of the latch, assembly of the product.

The "conceptual design ontology" which contains the subject specific definition of the vocabulary and explicit terms in, Customer requirements information – as stated in communications and request for Quotations. Action plans – for manufacturing, engineering change, prototype construction, and for individual members of the development-team. Budgets of engineering equipment such as tooling, prototype, and cost tracking charts. Design calculations including simple mathematical equations and FEA analysis reports. Feasibility study information and Failure Mode Effect Analysis data to prevent failure (including historical data). Testing and Quality control standards and documentation (including physical tests such as impact testing, noise and fire tests). Supplier information, including contracts, legal documents and supplier capacity/capability. Manufacturing and assembly plans including BoM. CAD models of the concept and full designs, individual components and full assemblies. The data and information is classified into classes including some "abstract" classes where the same knowledge is shared between different super-classes of knowledge.
Once all the information was gathered the construction of a software example could be undertaken.

4 PROPOSED SYSTEM

The software architecture relies on a backend of a Collaborative Product development Environment (PTC Windchill R6.2) (see figure 1). Windchill enables the online collaboration, product data/document management and workflows/version control functions. This functionality is customisable using Java classes in windchill which allow the inheritance of features such as version-controlled and lifecycle-managed into a new class of documents to manage specifically items of knowledge and rules. However Windchill by itself does not provide the functionality necessary for concept creation (such as solid models, process plans or assembly plans) or the use and management of knowledge in an Expert System. In order to overcome this, a new user interface is being created for concept design generation and evaluation, that is accessible from the main windchill interface.

The software solution uses the LOCAM manufacturing planning system to generate preliminary process plans from STEP AP-224 "machining features for process planning" data. The STEP standard (5) ISO 10303-224 (2001) has been implemented in only one modeller so far (6) STEPTrans, formerly known as RPTS-MP is not available for use, so a new modeller to generate AP-224 files will be created, this will construct machining features from the primitives defined in the AP-224 standard as well as allow the entry of non-geometric data specified in the standard through the use of forms. The process plan can be generated for the full AP-224 model and the process plan optimised by selective inclusion and exclusion of features from the process plan generation to find the optimal set of machining features that can be manufactured using the capacity of the manufacturing plant (7, 8). The LOCAM system requires the creation of a full manufacturing database, in the fully automated generative mode, in order to process the machining plans. This database is stored separately to the main vault (managed by Windchill).

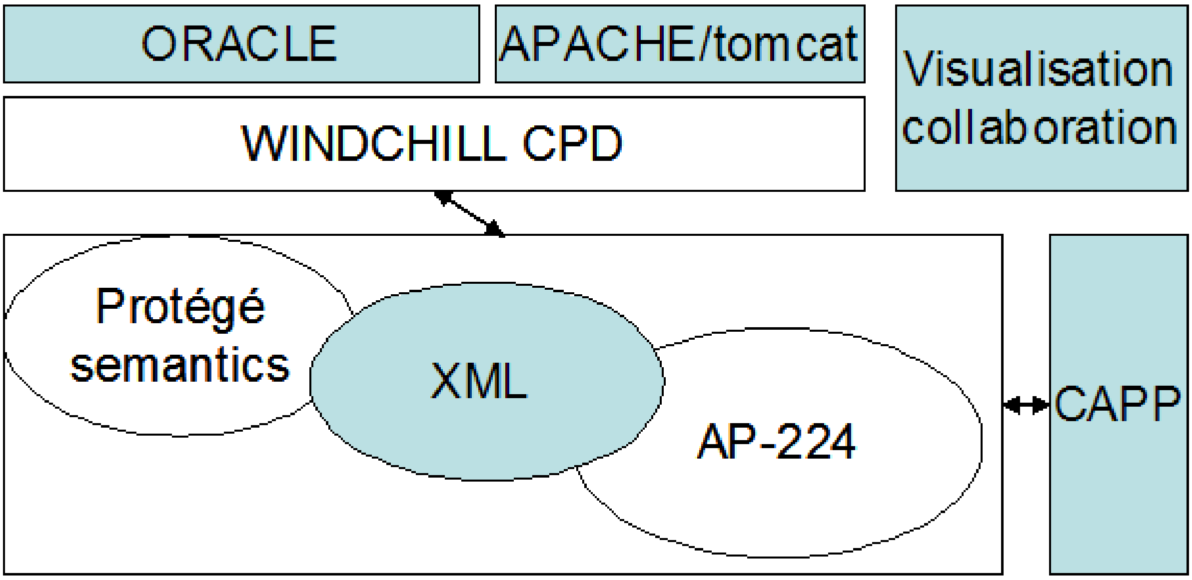

Figure 1: The Software Solutions for the Proposed System

The expert system is constructed using Protégé-2000 Expert System shell and the Java Expert System Shell (JESS). Protégé allows the form-based construction and maintenance of knowledge bases and ontologies in many formats including JDBC database CLIPS, XML and RDF. JESS is integrated within this integrated environment and provides the facilities to define rules (CLIPS DEFRULES) that are not available in Protégé by default. The knowledge base and rules created on the basis of the project information gathered from the latch product example and integrated with windchill through the use of a new class defined for knowledge.
As mentioned earlier, this class inherits many of the features of the standard windchill document class such as revision-control and lifecycle-manageability. The knowledge is stored with the other project documents in the same project cabinet and the extra attributes allows a more focused and accurate use and re-use of the knowledge both within the project and as a

reference in future projects. The system runs in client/server mode with an Apache web server, Oracle database, and separate LOCAM, Windchill and Protégé-2000 installations on the server machine. Client access is through a web-browser.

5 CONCLUSIONS AND FURTHER WORK

This referential re-use of the knowledge is one of the biggest added benefits of the Collaborative Product Development-Expert System integration approach. In addition, the ability to generate concept models based on ISO-STEP machining features and selectively generate process plans on the fly from the AP-224 model. This model can then be exported to downstream applications such as CATIA and PRO/Engineer for detailed design, negating the need to fully re-model the design once the concept has been approved, and ensuring that an approved concept does not have to be expensively redesigned at a later stage due to manufacturing/assembly problems.

The next stages of the project will see the creation of the AP-224 modeller and integration of the expert system with Windchill. The program runs from September 2001 to September 2004.

5.1 ACKNOWLEDGEMENTS

The project is financially sponsored by the Engineering and Physical Science Research Council, the industrial collaborators are ArvinMeritor, Mabey&Johnson, LSC Group and PTC Corporation.

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