Knowledge-Enriched Product Data Management System to Support Aggregate Process Planning

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SYNOPSIS

This paper is proposed a novel method to disperse manufacturing knowledge through the application of a Product Data Management (PDM) system. The intention of this new development is to support aggregate process planning during the early product development phases. The objective of the methodology is that manufacturing knowledge can be captured and reused within a distributed and collaborative environment. In addition, this paper also emphasises the way in which manufacturing knowledge can be encapsulated in a domain-specific ontology called 'manufacturing know-how'. Its semantics can be translated through the application of web-based technologies so that it would enrich the value of manufacturing knowledge being managed and promote the sharing of that knowledge within a distributed and collaborative environment.

1. INTRODUCTION

In today's highly competitive industrial environment, design and analysis of manufacturing and process plans for complex products require a very high degree of 'know-how' [(1), (2)]. Suitable tools are required to recover and store this vital information, and make it available on a company-wide basis. Companies therefore, must re-examine the ways to store and share this kind of information, and the development processes that use this information. Modern manufacturing companies deploy different software systems to store all types of information about their products. In particular, more companies nowadays use PDM systems which can provide easy access, control, changes, support and fast availability of data.

Manufacturing knowledge is recognised as one of the greatest assets for a company involved in product development. However, little has progressed beyond the scope of using it in a distributed and collaborative product development processes, specifically in supporting process planning. More recently, there have been a number of researchers whose aim was to develop knowledge-based process planning systems. For example, Shi et al [3], developed a knowledge-based process planning system for automotive panels. The system consists of three subsystems namely process planning, forming analysis and knowledge-based, functions which are associated with each other. The system uses case-based, rule-based reasoning techniques to help engineers make the right decisions. Law et al [4] developed an objected-oriented knowledge-based computer-aided process planning system for bare circuit boards manufacturing. The system is used to capture process constraints and planning knowledge to perform comparisons with experienced process planners. Tiwari et al [5] developed a case-based computer-aided process-planning system for machining prismatic components. The system reuses previous experience automatically to generate new solutions or generate new plans when no appropriate old solution exists.

None of the systems, however, are currently exploited in the area of utilizing advanced tools such as a web-centric PDM system, which can ease the problems of capturing the appropriate information of manufacturing 'know-how' to support process planning. The main challenge of the research reported in this paper is to develop a knowledge-based system to support the above problem. The application of this particular tool not only provides significant improvements in communications, it can also be used to support manufacturing operations by providing an open source environment for information sharing and retrieving. The objective of the following sections in this paper is to propose a Manufacturing 'Know-how' approach in order to enrich a PDM system and describe how it can be integrated with the CAPABLE Aggregate Planning Engine [6]. The impact of this approach is to facilitate decision making and data delivery for faster process planning.

2. THE AGGREGATE PROCESS PLANNING CONCEPT

Aggregate Process Planning is a methodology, developed at the University of Durham for the selection of the most appropriate processes and resources and the automatic creation of "rough-cut" processing information from early feature-based product models. The purpose of Aggregate Process Planning is to allow alternative process plans (or routing) for custom parts to be generated, evaluated and improved based upon estimated *manufacturability* before committing to a fully specified product model and supplier.

A "Knowledge-Enriched CAPABLE Aggregate Process Planning" system for aerospace applications has been developed [6] by capturing and representing product and process knowledge during aggregate planning and subsequently prioritising knowledge using the theory of Capability Analysis [7] to produce a realistic process plan. CAPABLE/Space is a software implementation of Knowledge-Enriched Aggregate Process Planning which utilises intelligent, "data-resistant" planning algorithms to automatically explore process and resource alternatives from the enterprise model, seeking a process plan which results in near-optimal manufacturability as determined by quality, cost, lead time and knowledge (QCD+K) criteria. This research seeks to enhance CAPABLE/Space functionality by providing a PDM-based methodology for knowledge management within a distributed and collaborative environment.

3. KNOWLEDGE-ENRICHED PDM SYSTEM

3.1 Background of Manufacturing Know-how

Over the years there have been many research approaches established around using knowledge management to support product development. Nevertheless, this traditional technique needs to be pushed to a higher level by using advanced technologies and other supporting software systems. In industry, knowledge management is often used interchangeably with knowledge know-how from design to manufacturing, whether its context is described explicitly or implicitly. In a manufacturing context, this knowledge representation is often regarded as qualitative and quantitative. In this paper, the qualitative and quantitative knowledge can be encapsulated as a domain specific ontology, known as 'manufacturing know-how', as indicated in Figure 1. This particular part of the research exploits the possibility of applying this information to support process planning. Hence, in order to generate manufacturing or assembly process plans the require parameters of the resources are important to determine an optimum manufacturing operation sequence. Also, by adding manufacturing know-how and design knowledge together with a capability analysis technique, this can enhance and improve the generated process plan [(6), (7)]. Furthermore, the knowledge captured in a PDM system can be distributed to various locations and storing the manufacturing know-how of the collaborators subject to predefine agreements. Another aspect of this approach is to investigate 'how can this information be stored to ensure a [1]single context?' so that, it would enrich the value of the information being managed and promote the sharing of that information.

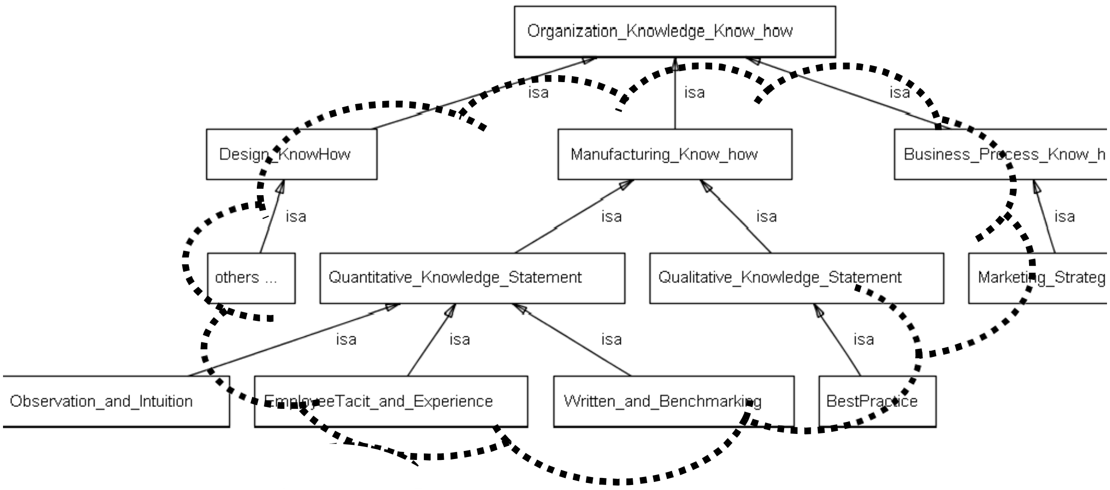

Figure 1. The Manufacturing Know-how Ontology

3.2 The Technical Approach

Figure 2, outlines the Knowledge-Enriched PDM representation and its supporting technologies. The Knowledge-Based System (KBS) is constructed using an integrated software tool Protégé-2000 [(8)], supported by Resource Description Framework (RDF) and

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[1] To eliminate the miss-interpretation by various departments involved in a development process. Hence, they must also ensure that multiple departments can easily and unambiguously interpret the information and access that knowledge at any point in the process.

EXtensible Markup Language (XML). RDF was developed by the World Wide Web Consortium (W3C) to complement XML for modelling semi-structured metadata *(for example, documents and emails)* and enabling knowledge management applications. In particular, RDF is a general-purpose language for representing information on the Web which has a recommended XML serialization form [(9)] to be used to encode data models for exchange of information among applications. RDF can use values represented according to XML schema datatypes [(9)], thus assisting the exchange of information between RDF and other XML applications. Furthermore, an RDF document is used to derive the semantics and context from the Universal Resource Identifier (URI) and metadata attached to every entity. The KBS is then used to integrate with Windchill PDM system using Protégé's Java API. The instances of the captured knowledge representations will be stored as objects in a Windchill PDM Cabinet [(10)]. Hence, this allows the knowledge to be shared, modified and reused by the CAPABLE Aggregate Process Planning System.

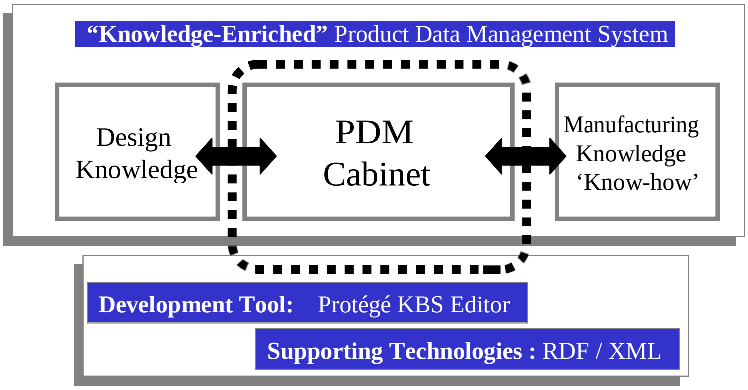

Figure 2. 'Knowledge-Enriched' PDM

4. INTERACTIONS OF KNOWLEDGE-ENRICHED PDM SYSTEM DURING EARLY PROCESS PLANNING

A conceptual representation of the interaction between a "Knowledge-Enriched" PDM system and the CAPABLE Aggregate Process Planning system is illustrated in Figure 3. The initial stage of creating the interactions is to define a "workflow" for a product and process development of a specific company. Workflow processes determine what happens within each task of the product development phases. For example, during the early design stages from conceptual to embodiment, a product definition is generated and the information is stored in an Oracle Database. The Windchill PDM Cabinet stores this information in a "cabinet and folder" hierarchy from general to specific topics. In addition, the PDM Cabinet also can provide methods of locating information. During the early development stages, the design engineers may be required to access the knowledge-based system to obtain the appropriate design knowledge and manufacturing know-how. The design engineers then select the relevant knowledge to refine the design and subsequently interrogate the CAPABLE Aggregate Process Planning system to obtain a preliminary process plan. The new process plan is then delivered through the XMI Stream to the PDM system for Plan/Review, and subsequently is being readied for implementation.

The intention of XMI (XML Metadata Interchange Format) is to propose a way to standardize Extensible Markup Language (XML) for users to exchange information about Metadata in distributed heterogeneous environments. 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 share complex information [(11), (12)]. XML bridges part of the 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 [(13)]. 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. Additionally, the stream format is also contained 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. The application of XMI and XML in this scenario will contribute a potential industrial benefit to improving both design quality and production decisions in a collaborative environment.

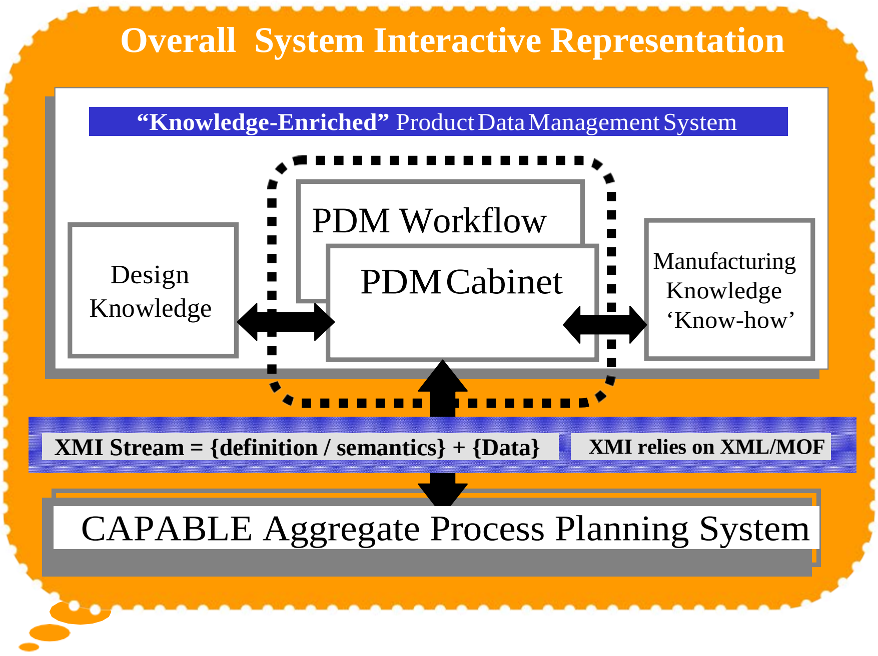

Figure 3. Overall System Representation

5. CONCLUSIONS

This paper has outlined a method of capturing and reusing manufacturing know-how and design knowledge to support process planning within a distributed and collaborative environment. A prototype of the proposal is currently under development [(14), (15), (16), (17)]. The objective of this part of the work is manufacturing know-how biased as opposed to dealing with design know-how [(18)]. The advantages of this approach include the enhancement of current PDM technology and the ability for companies to learn through utilising the relationships of an external production network. In terms of advantages in technical aspects, the implementation proposed in this paper is embarking on a new breed of advanced web-based and PDM technologies to develop a system within an open source environment. This is regarded by many, as the development tools for the future of enterprise collaboration.

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