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PLM Systems for Network-Centric Manufacturing

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Abstract

The concept (and implementation) of Product Lifecycle Management (PLM) has drawn much attention in both industry and academia. This paper investigates the scope of PLM systems, presents different types of PLM architecture and identifies an appropriate definition of PLM for a Network-Centric Manufacturing paradigm with a specific focus on small manufacturing enterprises. Research issues of PLM such as interoperability of product data model and standards of data exchange, system architecture, and the intellectual property protection are discussed. The paper concludes with guidelines for development of the next generation PLM software systems so that they can be cost effectively applied in a manufacturing systems environment.

Keywords: Product Lifecycle Management; PLM architecture; Network-Centric Manufacturing; interoperability; Intellectual property.

1 Introduction

Even though the product lifecycle concept has represented a central element of manufacturing and marketing theory since its development in the 1950s, it is only recently that it has begun to attract attention due in large part to its broad scope and possibilities of collaborative design within national boundaries and in trans-national environments.

The concept of Product Lifecycle Management (PLM) was derived from Product Data Management (PDM). This can broadly be defined as a way for engineers and suppliers to talk amongst themselves via networks as products evolve through their lifecycle. An ideal PDM/PLM system manages all forms of product data, which could include CAD files, text files, or any other information related to the product development. The broad scope of PLM has allowed it to emerge into a primary means by which to improve product development processes across the value chain in order to deliver the most business value.

2 Scope of PLM

Generally, PLM enables collaboration within and between enterprises [1]. The scope of PLM is not well defined and concepts are not yet been firmly established either in academia or industry. Based on a detailed literature review of both archival and industrial journals, we have developed a proposed definition of PLM as follows:

Product Lifecycle Management is the product information management process by which a product is evolved from conceptualization, detail design, manufacture, distribution, maintenance, and recycling. Product Lifecycle Management includes the subsystems of Enterprise Resource Planning, Product Data Management, Document and Knowledge Management, Collaboration and Process Management, Total Quality Management, Customer Relationship Management, Supplier Relationship Management, and Environment, Health and Safety Management.

Figure 1 details the different elements of the lifecycle of a typical engineered product and places it within the context of a PLM system. Note the two perspectives or views (role based versus functional) that can be taken in developing software modules.

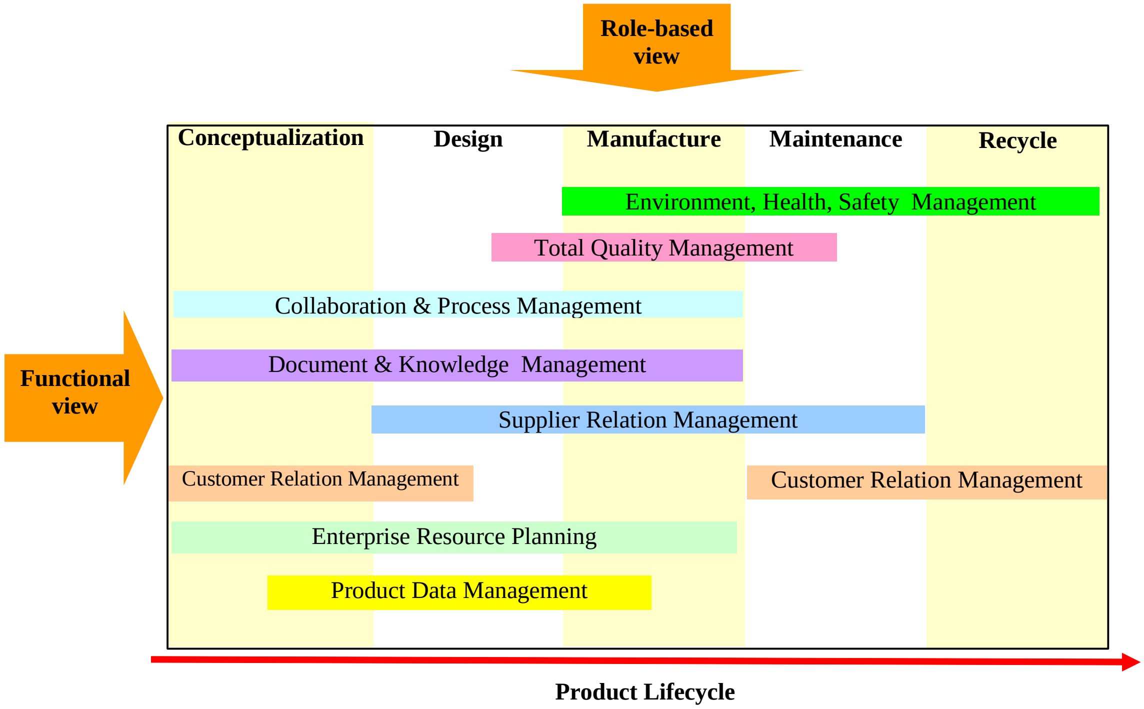

Fig. 1 Subsystems within a product lifecycle management (PLM) system.

In Table 1, each of the sub systems is explained. It must however be noted here that these modules are not mutually exclusive or discrete. They are closely inter-related and data is freely exchanged from one to another.

3 Current Commercial PLM Software Systems

PLM solutions are a unique combination of software, middleware, hardware and services that put allow data to be the core of the product development process. This enables the organization to extract greater value from data, collaborate in a more effective manner, streamline processes, improve employee productivity, and set the foundation for innovation. Here, we briefly summarize the major PLM systems available in the marketplace today.

UGS, Dassault Systemes, and PTC are three of the largest PLM vendors. The UGS Velocity Series is a series of modular, yet integrated solutions that is focused towards the needs of the mid-market [2]. It consists of a preconfigured family of modules encompassing digital product design, engineering analysis and data management software modules. PLM software from Dassault Systeme/IBM promises to help foster innovation by tailoring or customizing an appropriate combination of application software, middleware, hardware and services for a successful PLM implementation. CATIA, ENOVIA, and SMARTEAM also provide flexible product data management and business process management systems [3]. Parametric Technology Corporation (PTC), makers of Pro/Engineer software have extended their scope and now market a suite of product development and information management solutions utilizing a ‘Product First’ philosophy. This is centered on the idea that great products make great companies, which helps companies identify and realize value in their product development process [4].

There are also smaller software vendors providing PLM software such as Agile [5], Matrix One [6], Omnify [7], Arena [8]. Their packages are mainly targeted at small and medium sized enterprises. Their products typically provide bi-directional interfaces with design (CAD/CAE) tools and enterprise systems (ERP/MRP/CRM).

Table 1. Sub Systems within a Product Lifecycle.

Subsystem	Function	Scope
Enterprise Resource Planning	A broad set of activities supported by multi-module application software that helps a manufacturer or other business manage the important parts of its business.	ERP includes product planning, parts purchasing, inventory maintaining, interacting with suppliers, providing customer service, and tracking orders, as well as application modules for finance and human resources aspects of a business.
Product Data Management	An information system used to manage the data for a product as it passes from engineering to manufacturing	Data includes plans, geometric models, CAD drawings, images, NC programs as well as all related project data, notes and documents. A PDM also manages the interrelationships between the data so that when changes are made to one database, the effects are highlighted in the others.
Document Knowledge Management	A secure and intelligent information repository to retain enterprise knowledge about processes of creation, production and distribution of products such that employees are able to search and find records and solutions easily.	The electronic records of engineering, business, legal records in different formats such as emails, pictures, audio, video, text, database.
Collaboration Process Management	A role-based communication platform that allows geographically distributed users to collaborate on projects.	It supports multimedia communication, virtual teaming, project planning and scheduling, which focuses on human communication.
Total Quality Management	An organizational undertaking to improve the quality of manufacturing and service.	It focuses on obtaining continuous feedback for improvements and refining existing processes over the long term.
Customer Relationship Management	Methodologies, software, and Internet capabilities that help an enterprise manage customer relationships in an organized way.	It is a database about customers that described relationships in sufficient detail so that management, salespeople, service people, and customer can directly access information, match customer needs with product plans and offerings, remind customers of service requirements, know what other products a customer had purchased, and so forth.
Supplier Relationship Management	Management of the flow of information between suppliers and purchasing organizations and the integration of supplier information in the procurement process, which helps to manage strategic sourcing and spending.	SRM provides common frame of reference to enable effective communication between an enterprise and suppliers with different business practices and terminology. It provides information of suppliers' capabilities as well as decision-making support.
Environment, Health & Safety Management	EHSM provides proactive decision-making support for product and process related health and safety information and knowledge as well as risk management.	It provides information and guideline to comply regulatory and standards regarding material, process, and environment health and safety and decision support.

4 Research Issues in PLM

As part of our detailed literature review, we identified three major dimensions of PLM that can be further dissected and researched. These are:

a) Data Exchange Standards,
b) Cross-domain data exchange and interoperability, and
c) Information Security and assurance.

Each is now discussed.

4.1 Data Exchange Standards of PLM

The major data exchange standards of PLM include:

4.1.1 IGES/STEP

Since 1984 the International Organization for Standardization (ISO) has been working on the development of a comprehensive standard for the electronic exchange of product data between computer-based product lifecycle systems [9].

The Initial Graphics Exchange Specification (IGES) was the U.S. national standard for the exchange of data between dissimilar CAD systems. It only included basic geometry information. As industry requirements evolve and more information is exchanged, IGES has been replaced by new standard STEP, whose scope is much broader. STEP is intended to handle a much wider range of product-related data covering the entire lifecycle of a product. In STEP, the implemental parts are known as Application Protocols (APs). Each AP is applicable to one or more lifecycle stages of a particular product class. However, the APs themselves are constructed on the basis of a set of Integrated Resources (IRs), defining fundamental constructs that can be specialized and applied for a wide variety of purposes. STEP standards are mainly being developed by the consortium PDES, Inc [10].

4.1.2 VRML/X3D

Virtual Reality Modeling Language (VRML) is a traditional mechanism to visualize geometric representation of engineering artifacts through web. X3D is an eXtensible Markup Language (XML) enabled 3D file format to enable real-time communication of 3D data across all applications and network applications [11]. It has a rich set of features for use in engineering and scientific visualization, CAD and Architecture, Medical visualization, Training and simulation and more. X3D is a considerably more mature and refined standard than its VRML predecessor.

4.1.3 JT-Open

JT Open is UGS's main thrust to support product visualization in engineering collaboration. Open collaboration across extended enterprises makes it possible to view and share product information throughout the product lifecycle [12]. JT Open enables application end users, independent software vendors and other likeminded parties to join a community-of interest committed to establishing JT as the one of the de facto technologies for 3D visualization, collaboration and data sharing in today's auto industry.

4.1.4 XML

XML is an emerging format for facilitating product lifecycle interoperability, which starts being adopted by major PLM vendors (e.g. PLM-XML from UGS and 3D XML from Dassault Systemes). The advantage is its openness based on standard W3C XML schemas. Representing a variety of product data both explicitly and via references, XML can provide lightweight, extensible and flexible mechanisms for transporting high-content product data over the Internet, and aims to form the basis of a rich interoperability pipeline connecting PLM products and third party adopter applications for documentation, report, and presentation.

Interoperability issues within and between organizations using software applications to conceive, develop, engineer, manufacture, and maintain products cost industry billions of dollars annually. Initiatives to improve interoperability in heterogeneous application environments are therefore of vital importance, and consumers are demanding unprecedented levels of interoperability between PLM software applications to help accelerate critical business process threads, increase ROI, and augment time to market advantage.

4.2 Cross-domain data exchange and Interoperability

PDM tools have been used by manufacturing companies to manage the data and documents accumulated in the design of their products. System features typically include data vault and document management, product structure management, project program management and workflow definition management, including data vault and document management, product structure management and project program management [13].

XML standards can be used for syntax-level interoperability and multidisciplinary constraints capturing to support knowledge exchange [14]. Semantic level interoperability to prevent semantics loss and intent representation in cross-domain communication can also be achieved through XML/RDF [15,16].

4.3 Information security and assurance

A PDM system manages and stores product design, manufacturing and support data [17,18]. Initially the focus of PDM systems was solely on design and engineering. Later, the need for secure data management and control of the product development process throughout the entire product life-cycle (from idea generation to product discontinuation) has expanded the requisites of PDM systems even further.

With external participants, such as suppliers and technical partners as effective players in product development teams, these information systems were expanded and modified to use world-wide web functionalities. At the same time these advances brought up major concerns with security and disclosure of private information [19]. Role-based access control is indispensable in PLM systems for information assurance [20, 21]. Data needs to be shared selectively with distributed and partial data modeling scheme for security-aware communication [22].

5 PLM Software Systems: Guidelines for Future Development

To be successfully deployed in a manufacturing environment, PLM software must accommodate the needs of both industry and the government including regulatory issues. An ideal PLM system must also have seamless interfaces to interact with the myriad of legacy PDM, ERP, and DBMS systems that are currently in use. Interfaces with other engineering software systems such as Finite Element Analysis and Computer Aided Manufacturing systems (tool path planning, etc) are equally important. PLM systems must also provide enough flexibility to accommodate needs from different industry sectors, which poses a challenge to the software component design of PLM systems. A modular and plug-n-playable approach will be advantageous in long run. As environmental issues captivate the attention of consumers, PLM systems are expected to be the most heavily used engineering software to maintain relevant documentation. Compliance warning and integration with government regulations will be also one of the most important features in future PLM systems.

The evaluation criteria of PLM systems need to include not only ease of use, market share, potential for improvement of core competencies, and return of investment to customers and users.

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