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Product relationships management enabler for concurrent engineering and product lifecycle management

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ABSTRACT

The current competitive industrial context requires more flexible, intelligent and compact product lifecycles, especially in the product development process where several lifecycle issues have to be considered, so as to deliver lifecycle oriented products. This paper describes the application of a novel product relationships management approach, in the context of product lifecycle management (PLM), enabling concurrent product design and assembly sequence planning. Previous work has provided a foundation through a theoretical framework, enhanced by the paradigm of product relational design and management. This statement therefore highlights the concurrent and proactive aspect of assembly oriented design vision. Central to this approach is the establishment and implementation of a complex and multiple viewpoints of product development addressing various stakeholders design and assembly planning points of view. By establishing such comprehensive relationships and identifying related relationships among several lifecycle phases, it is then possible to undertake the product design and assembly phases concurrently. Specifically, the proposed work and its application enable the management of product relationship information at the interface of product-process data management techniques. Based on the theory, models and techniques such as described in previous work, the implementation of a new hub application called PEGASUS is then described. Also based on web service technology, PEGASUS can be considered as a mediator application and/or an enabler for PLM that externalises product relationships and enables the control of information flow with internal regulation procedures. The feasibility of the approach is justified and the associated benefits are reported with a mechanical assembly as a case study.

1. Introduction

The current academic and industrial product lifecycle management (PLM) vision—that consists in setting up a comprehensive set of models, methodologies, processes and information systems covering the entire product lifecycle [1–3]—has not yet fulfilled all life phases' requirements [5,4,6]. This is particularly right at the beginning-of-life (BOL) phase where product designers, process engineers, and assembly planners are still working separately without any recovery, overlap or feedback loop facilities/features in their tasks. Past research efforts have led to successful design for X (DFX) and knowledge-based techniques in product design in order to integrate all constraints of each life phases (i.e. manufacturing, assembly, disassembly and recycling) [7,8], but some gaps still exist in the management of the various technical entities and the control of information/decision/rationale flow through the product lifecycle [11]. This becomes a barrier for applying an efficient concurrent engineering philosophy in BOL and remains a huge challenge to be tackled [9,10].

Previous work argued that companies required efficient concurrent engineering (CE) [12] and PLM strategies [11] in order to maintain their business competitive edge. One particular industrial requirement is the need for concurrent considerations of lifecycle issues for different life aspects into the early product design process [13–15]. It is clear that current product geometry—based on traditional part and feature oriented modelling approaches—only

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Nomenclature

PLM	product lifecycle management
PDM	Product Data Management
MPM	Manufacturing Process Management
CAD	Computer-Aided Design
CAPP	computer-aided assembly process planning
BOL	beginning-of-life
DFX	design for X
CE	concurrent engineering
ASP	assembly sequence planning
AOD	assembly oriented design
PROMA	PROduct relationships Management Approach
PASODE	Proactive ASsembly Oriented DEsign
MUVOA	MUlti Views Oriented Assembly
ASDA	Assembly Sequence Definition Algorithm
ERP	Enterprise Resource Planning
SCM	Supply Chain Management
BOM	bill of material
eBOM	engineering bill of material
mBOM	manufacturing bill of material
BOR	bill of relation
UML	Unified Modeling Language
XML	eXtensive Markup Language

represent a limited view of product lifecycle information, and have limited benefits for CE and PLM strategies [16,17]. To overcome these difficulties, this paper proposed a Product design Engineering based on Generative Assembly SeqUenceS planning (PEGASUS) application and it is aimed to bring the potential benefits of CE into this integrated and concurrent product design and assembly sequence planning (ASP) stages.

Using previous research results related to assembly oriented design (AOD) and PLM issues [18], the paper presents the implementation of an approach, which aims to reveal the relationships among product parts and operations as well, and maximize the usage of these relationships whilst maintaining information consistency [19] and seamless flow between product design and ASP phases [11].

In Demoly et al. [20–22] a research background and framework entitled Proactive ASsembly-Oriented DEsign (PASODE) as well as a multiple views model called MUltiple Views Assembly Oriented (MUVOA) [23] and the Product RelatiOnships Management Approach (PROMA) to manage product relationships have been described in detail [11]. Here, the implementation of PROMA into a new PLM hub application called PEGASUS is detailed and it is carried out by using framework and models described in [22]. This approach implementation also uses web service technology to provide wider and easier access and distributed design and working, which is part of latest implementation efforts in PLM systems [25]. The whole approach is intended to extend the traditional PLM systems capabilities to be a new lifecycle oriented application with new theoretical model.

Section 2 presents a survey on current PLM systems implementations status in industry. This survey is followed in Section 3 by the description of the research background in terms of model, framework and approaches. Section 4 introduces the description of the PROMA application in PEGASUS, which is based on web service technology and used C# as programming language. The implementation aims to enable the reasoning and control of information flow between PDM (Product Data Management) and MPM (Manufacturing Process Management) systems, and CAD (Computer-Aided Design) applications. Last, considering the implementation as a prototype, an industrial case study has been undertaken and is detailed in Section 5, so as to demonstrate the applicability and the benefits of PROMA and PEGASUS.

2. Survey on application status of PLM systems in industry

Introduced at the beginning of the 2000s, the PLM strategy consists of the management of the whole product data-information-knowledge for its entire lifecycle [1,6]. This research topic has since also received much attention from industry where current practices are more focused on the management of product technical data and associated workflows through various engineering systems [24]. As such, many industrial engineering departments have tackled PLM issues, essentially in BOL and Middle-Of-Life (MOL) of the product, by implementing methodologies into various systems such as PDM, Computer Aided X (CAX), MPM, Enterprise Resource Planning (ERP), and Supply Chain Management (SCM) systems in a single and global digital environment, where all enterprise departments have a role to play [20].

In the above defined context of CE, several research issues have to be investigated and tackled on current industrial practices in PLM systems, especially on PDM and MPM systems [26,27]. Specifically, a PDM system is intended to ensure that the right information is available for the right person at the right time and in the right format by introducing various functionalities such as versioning, bill of material (BOM) management, workflow management, check-in/check-out procedures, and engineering change and configuration management to name a few [28,29]. Regarding engineering design data that consists of parts, subassemblies, BOMs, specifications, analysis results, configurations and so on, PDM systems can be considered as product model storage systems and still be centred on product information usually embedded and sometimes hidden in files and documents [11].

In addition to the above concerns, a lack of associativity in PLM systems has also been highlighted [30], where only ‘‘parent–child’’ (i.e. ‘‘is part of’’ class) relationship exists. For a large scale company, the management of relative positions of parts using positioning matrices is implemented in PDM systems in order to be more closely related to geometric models defined in CAD systems, and to facilitate change management and part positioning [32]. Furthermore, other authors [33,34] have proposed an advanced PDM system based on a property-driven development/design (PDD) approach by introducing the handling of predicted engineering characteristics (i.e. structure, shape and material) and properties (i.e. product's behaviour) of the product with their interdependencies in a separate manner. However, information related to product relationships and assembly process engineering is not effectively treated in their proposal. PLM systems have moved towards web-based and web service technologies, in order to facilitate information exchange and access in distributed and extended enterprises [7,25]. An additional effort towards ontology and semantic web can also be found [35–38]. Recently, Cantamessa et al. [39] in their PLM implementation survey have stressed a similar need about the future role of PLM in supporting and coordinating knowledge by allowing easier access to product data and embedded tacit knowledge.

According to the above applications and approaches, a lack of support of associability among product models using product relationships still exists and is a barrier for effective and integrated lifecycle oriented design [16,30,17].

At the interface of Computer Aided Assembly Process Planning (CAAPP) and ERP systems, MPM systems enable the management