Integration of CAD knowledge with PLM: Application to product development process during requirements clarification and detailed design phases

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Abstract: PLM has become a major subject of research in the past decade. It includes research works in engineering fields, information technologies and human science. Dealing with the interactions of numerous experts in a common software environment, PLM presents major difficulties resulting from these interactions. The paper presents research works dealing with CAD and PLM data exchange. A system is developed to enable the transfer of relevant data from the CAD to the PLM in order to enrich the PLM Database with expert data resulting from the design activities. The user interface is integrated to the CAD System and provides a friendly interface for distinguishing the relevant data to be transfer to the PLM System. A transfer protocol is presented, based on XML technology. This transfer enables the link with other fields of product development through the use of PLM functionalities. Finally, an example is provided to illustrate the research conducted.

Keyword: Product Lifecycle Management, CAD Knowledge, Data Exchange

1 Introduction

PLM has become a major subject of research in the past decade. It includes research works in engineering fields, information technologies and human science. In the field of product development, research works have been conducted in the domain of collaborative engineering, data exchange and knowledge management. The paper deals with PLM research works and focuses on data exchanges resulting from the integration of expertise into a shared PLM database.

PLM deals with the interactions of numerous experts in a common software environment. One of the major difficulties resulting from these interactions is the definition of a common data model. This model has to be compliance with the different systems used by experts. However, the use of a common data model tends to complicate the integration of expert applications. Then, data and knowledge are often lost during the lifecycle phase interactions.
The paper presents first existing PLM research, from the preliminary applications mainly managing CAD models towards the PLM applications managing the whole data handled during the product lifecycle. Research works are presented dealing with knowledge capitalization and sharing.

Then, we focus on the transfer between an existing CAD and a PLM during the requirements clarification and the detailed design phases. The difficulties regarding the update of CAD model is presented. In order to provide an integration of parameters issued from functional requirements clarification into the CAD system, through the use of a PLM system. A demonstrator environment is implemented. This environment enables the mapping between specific CAD knowledge attributes with the meta-data handled into a PLM. It offers functionalities for transferring the attributes in a bidirectional way, between a PLM and a CAD, based on an XML technology. A full integration into a commercial CAD is presented and first issues are discussed. The environment is assessed through the implementation of a use-case that deals with multi disciplinary expert activities in a PLM context. It provides data exchange capacities that enable the transfer of relevant data from a CAD file to a PLM database.

Finally, a conclusion summarizing the preliminary results is presented and future works are mentioned.

2 From the development of CAD-oriented PDM towards the emergence of PLM Applications

This section presents an overview of the development of PLM researches [12]. It introduces the evolution of the need for managing data, started with the design phase and impacting the whole lifecycle phases in the new PLM Applications context.

In the domain of PLM research, we can distinguish three major sub-domains that deal with:

- data management, infrastructure of PLM Applications and standards of exchange
- organization of the lifecycle phases, human interactions with the PLM Applications
- knowledge management, capitalization and reuse

Each of these domains deals with common aims and proposes solutions for improving existing PLM Applications and their use.

2.1 Data management and structuring of PLM Applications

The research works dealing with data management and infrastructure drive to the identification of product structure, managing and storing all the information related to design, manufacturing or in-service support phases [7], [3]. It is based on the use of metadata for the data classification and configurable links between the metadata [4].

Some of the most important functionalities [7] of a PLM are:

- Storage and structuring product data
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- Classifying data
- Managing product change (modification of data, creation and deleting of information)
- Ensuring the access of the product data in a secure way
- Controlling the processes
- Managing project organization, teams and roles
- Distributing the product data
- Enabling the user to visualize the product data

Based on these requirements, developments have been conducted in the research community and industries. These industrial R&D led to the development of commercial PDM like Dassault Systèmes, MatrixOne, PTC, Unigraphics, SAP, etc.

Concerning the research field, many works have been published. [15] presented a configuration-oriented product system based on knowledge management. This work was applied to made-to-order manufacturing enterprises and presented interesting results. [13] presented a computer-aided system enabling the designers to capitalize and share knowledge issued of preliminary tasks of a product development project.

Based on these researches, basic engineering fields can be interconnected, such as design, manufacturing, prototyping, etc. This interconnection implies improvement in terms of exchange and share of data through the use of multi heterogeneous applications which tends to the development of specific product development platforms using neutral formats (STEP, IGES, etc.) [8], [9].

### 2.1.1 Organization of PLM activities

The organization of PLM activities implies to deal with multiple aspects of the PLM researches: From the IT-requirements, in terms of technology integration, data and network security, hardware and software maturity, towards the management and human science, in terms of acceptance, usability of the applications, cognitive interaction with computers.

As this research work is mainly based on IT-factors and data integration, we focused first on prior researches done in this domain. We can mentioned the VPM-Chain project [5] that provides a single and secured storage for CAD or CAE data linked with product structure and workflow, in aeronautics industry.

### 2.1.2 Knowledge Management in PLM Applications

Knowledge management becomes strategic in engineering science domains [6]. The first applications started with artificial intelligence [2] and were incorporated to CAD Systems [13] Research works have been conducted in the domain of design knowledge [15], [11] and the definition of “knowledge” includes various entities [14]. In this paper, knowledge is seen according to the definition given by [10] knowledge is ‘… the entirely of skills and abilities used by individuals for a problem solving. Knowledge relies on data and information and is always bound to persons.’ In this context, our work on a data
management is concentrated of knowledge management rather than on a human approach. This approach enables the identification of key elements, block divisions, for knowledge management. From the six original block divisions [1] propose to add two new blocks defining a control cycle. The eight blocks obtained are:

- Knowledge Identification (overview of existing knowledge inside and outside of the company)
- Knowledge Acquisition (company’s decision to obtain knowledge from inside and outside, such as partners, suppliers)
- Knowledge Development (complement of knowledge acquisition, it symbolizes the action of knowledge creation)
- Knowledge Dissemination (enables the dissemination of knowledge)
- Knowledge Utilization (the main purpose of the process)
- Knowledge Retention (consists in the separation of valuable knowledge from the obsolete one)
- Knowledge Goals (determines basic goals in the company)
- Knowledge Assessment (consists in evaluating the achievement of the basic goals and taking decisions to improve the solution adopted)

In this paper, we present the first step of the research in the domain of knowledge management by identifying solutions for mapping knowledge issued from functional requirements to the CAD model generated during the design phases.

3 Protocols for exchanging between activities through the use of PLM functionalities

3.1 Objectives

As it has been presented below, the PLM aims to offer a centralized product data structure to aid product development teams. This product data structure is developed for enabling the exchange with various software including, Project Management Applications, Communication Facilities and Expert Applications. In this organization, the PLM function is to present multi views of the data and to ensure security access and storage.

Then a standard PLM organization can be understood as a centralized network as presented in figure 1.
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Figure 1 A standard PLM network and the proposed solution

This centralized network makes difficult the link between expert activities of the global product development process. For example, the data transfer between functional requirements clarification tasks and preliminary design tasks is performed through the use of PLM functionalities. These functionalities do not take into account the specificity of the expert tasks and tend to amplify the number of routine tasks. For example, a change in the basic requirements of the product does not imply any change in the design of the product. In order to operate an update of the design after a change of requirements, we present a protocol for exchanging information between expert tasks in a product development process. This protocol is organized within the relevant parameter engine illustrated in figure 1 and tends to links preliminary and detailed design tasks.

This protocol enables:

- The enrichment of the data stored in the PLM by enhancing the relevance of the attributes describing the database meta-classes.
- The automation of basic updates on the design resulting from modification of the requirements data.

The relevant parameter engine enables the selection of the parameters to be modified (updated). For example, the CAD file is built using specific driving parameters that controlled the design of the product. This relevant parameter engine is based first on the choice of the CAD expert and second on the parametric technologies supported by current CAD systems.

The aim is to offer a cross domain interface dedicated to the expert tasks between functional requirements clarification and preliminary and detailed design phases.

3.2 Aims of the developed system

As it has been presented in the first sections of the paper, a standard PLM Application does not take into account the direct links existing between lifecycle phases. In this section, we present a system enabling the link between two phases of the lifecycle, the
functional requirements clarification and preliminary design phases. This link is provided through the use of the PLM, in a remote way, in order to fulfill the needs of data integrity and traceability of the changes performed. The link concerns the parameters included in the CAD system and the ones specified during the requirement clarification tasks.

### 3.2.1 UML specification of the system

The system has been developed using UML. The first step of the development consists in the specification of the use case and sequence diagrams.

The diagram 2 illustrates the interaction between the developed system and the user. The links between requirements data and CAD parameters are set in the CAD system. Considering the designer does not use extra applications to achieve his/her tasks, this integration provides a friendly user interface for the designer. The parameters are transferred into the CAD system by the PLM: this exchange is carried out in a batch mode and are updated directly when the CAD model is opened.

**Figure 2** The use case diagram of the system

The sequence diagram 3 presents the achievement of a designer basic task. From the classical interaction with the PLM applications to the connection between the requirements data and CAD parameters, this diagram presents the successive operations that occur during the design tasks.

First, the designer receives the requirements by querying the PLM Database. The requirements are automatically integrated to a new CAD file.

Second, the designer performs his task and provides a parametrized CAD model based on this requirements. From this task depends the end of the sequence: the parametrized CAD model has to be robust enough in order to support all design changes. This robustness is largely depending on the design expertise and on the quality of the 3D-modeling. In this context, modelling methodologies has to be provided and best practises to be taken into account by the designers.

Third, the CAD data are stored in the PLM Database and the link with parameters issued from functional requirements clarification is provided using an XML file transfer.
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Figure 3 The interaction between the design actor, the PLM and the CAD System

3.2.2 Description of the XML file transfer

The link between the data of functional requirements clarification phase and the parameters of CAD modeling phase of the lifecycle is realized through the use of an XML file. This file is updated when a change occurs in the requirement clarification phase. XML technology has been used to provide integration with existing PLM and to simplify the link with CAD system through the use of Web technologies. Adding to that, XML Document Type Declaration (DTD) enables the declaration of new blocks. This characteristic provides efficient solutions that can be easily enriched with further version of the tool. We distinguish three types of blocks: the parameters, the rules and relations. The parameters are linked to the geometry, to the material. The rules enable the control of certain aspect of the design, such as activities of components, checks of best practices, etc. The relations enable the use of complex relations between parameters. In this paper, only the parameter issues are presented.

The XML file lists the parameters and values issued from the requirements clarification of the product to be designed. Each parameter is described in the file and documentation is provided to support the designer in his/her task. Figure 4 presents the parameter attributes. **ParameterType** Class lists the type taking into account into the CAD system. This list may change depending on the used CAD system. A simple extract of an XML file is provided in figure 5.
4 Application

The developed system uses the commercial PLM database ENOVIA with the integration of CATIA V5. This CAD system has been chosen because of the possibilities offered by CAA API in terms of customization.

The described use case concerns the design of a gear for knowledge-based engineering of gearbox. This example illustrates the use of the system proposed in this paper. It has been implemented to test the system and offers a simple but relevant example in order to illustrate our research work. Further examples should be implemented in the next months to check the usability of the system.

As shown on figure 3, the first step of the designer’s task is to collect the requirements from the PLM Database. The check-in check-out processes are not described because they are implemented in all the existing PLM and do not possess any research interest. The second step concerns the parametric design of the gear. The design of the gear is particularly important for two reasons:

- the parametric solution must support modification of the driving parameters
- the parameter issued from the functional requirements clarification phase are automatically added to the CAD model. However, the geometry has to be plugged to these parameters by the design expert.

The generated CAD file includes also the mechanical and geometry features describing a gear. Advanced parametric controlled are set enabling the link between the functional parameters and the geometry. This link is provided by the use of advanced visual basic functionalities that enable the activation / deactivation of rules and checks in the Part itself. The figure 6 presents the user interface that enables the designer to control the basic functional requirements driving the geometry. It also presents an overview of the PLM human interface offered by ENOVIA.
The third part of the design process consists in check-in the gear in the PLM database. Two files are stored regarding this simple product: the first one is the 3D part modeled in CATIA V5. It includes the geometry, the basic features and the parameters. In this example it also includes a Visual Basic interface that enables multi driving parameters depending on the choice of the designers. The second file is the XML file that lists the parameters issued from functional requirements available in the PLM database and that are used in the CATIA file. When opening the CAD file, a warning informs the designer that changes occurred in the parameters list and that update is needed. This XML file ensures the link between these two product development lifecycle phases.

**Figure 6** CAD and PLM human interfaces of the system

5 Conclusion

Product Lifecycle Management provides interesting issues in the domain of product development process. PLM offers a computer supported way for exchanging and collaborating during each phases of the product lifecycle but presents few possibilities in terms of exchange between phases.
In this paper, an environment enabling the exchange of relevant parameters between the functional requirements clarification and the preliminary design phases is specified and implemented. This environment offers the possibility to interact on the CAD model by modifying data stored in the PLM and therefore avoid time consuming in notification processes. If the environment is effective, the difficulties encountered during its definition in terms of data exchange illustrate the need for a flexible structure of the PLM Database. Moreover, the functionalities of the system have still to be analyzed using different case studies and design projects.

The first conclusions that can be drawn from now are:

- The commercial PLM available are based on a rigid database structure that does not allow major changes and does not take into account the reality of the product to be designed.
- XML exchanges used in the developed environment offer a way for managing data from a system to another but are limited in terms of implementation and required special developments for each PLM Applications

Further research works have to be conducted in the domain of data exchange for PLM applications. The next step of our work will concern the test of standard such as PDM Schema, PLMXLM, and PLM Enablers for data exchange between PLM applications.

References

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