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# Product Modeling during Its Whole Lifecycle for Collaborative Design in PLM*

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***Abstract*** - Product modeling and data exchange has been recognized as one of the sky issues of implementing a product overall lifecycle management (PLM) system. In this paper, a product integrated models during the whole phases of lifecycle is proposed first. Based on the integrated models, a multidisciplinary collaborative design method over Internet is discussed. STEP/EXPRESS, UML and XML are employed during the product modeling process. And a mapping relationship schema among different data schema is presented for product data exchange. Finally, a PLM prototype system is implemented based on J2EE, the proposed product integrated models. And primary technical ideas are validated.

***Index Terms*** - *Product modeling. PLM. STEP. XML. UML*

## I. Introduction

In the face of the turbulent dynamic global markets, manufacturing enterprises are forced into collaborating with their customers and suppliers more tightly in order to produce high quality products in smaller batches, with shorter lead times and more varieties. Utilizing PLM technologies in manufacturing enterprises is an efficient approach realizing the above objects, product modeling during its entire lifecycle is recognized to be fundamentally critical to implementing PLM systems.

Most of the developed currently product modeling methods focus mainly on one or some stages of the whole product lifecycle, such as design, manufacturing, assembly, maintenance, disposal/recycle, etc. Mike Rosenman and Fujun Wang presented CADOM (a Component Agent-based Design-Oriented Model) for collaborative design, which contains functional, structural and management data [1]. Ronald E. Giachetti proposed a standard manufacturing information model to support DFM in virtual enterprises, addressing the issues and requirements raised concerning management of DFM information [2]. QIU Xiao-li et al. present how to integrate STEP and XML as the neutral format model in network designing and manufacturing [3]. Matthew Simon et al. developed a self-contained data acquisition units for washing machines based on a microcontroller and non-volatile memory. The data has applications in design, marketing and servicing as well as end-of-life [4]. A STEP-based product modelling system for concurrent stamped part and die development is presented [5]. The system used a three-layer architecture ( application, logical and physical layers), and a new concept—Die & Product Integrated Information Model (DPIIM) is proposed to fully support the complete product data representation in concurrent stamped part and die development, then six EXPRESS-defined schemas are constructed to represent DPIIM. A product information modelling framework supporting the full range of PLM information needs is described [6]. The framework is based on the NIST Core Product Model (CPM) and its extension, the Open Assembly Model (OAM), the Design-Analysis Integration Model (DIAM) and the Product Family Evolution Model (PFEM). These are abstract models with general semantics, with the specific semantics about a particular domain to be embedded within the usage of the models for that domain.

Despite the many progresses, most of these modelling methods seldom consider problems from the view of the

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product overall lifecycle. Consequently, the research on product modelling of the overall lifecycle is very essential. In our previous research, a distributed remote robot product manufacturing system over Internet was developed [7]. In this system, product information model for the same product at different lifecycle stages, are represented by bill-of-materials (BOMs) and configurations.

The rest of this paper is organized as follows. Section 2 gives a review about product modelling methodologies. An integrated product models during its entire lifecycle is proposed in Section 3. Section 4 discusses a multidisciplinary collaborative design method over Internet. A mapping relationship schema among different data schema is presented in Section 5. Section 6 gives the implementation of the PLM system. Finally, concluding remarks about this research are given in Section 7.

## II. PRODUCT MODELING METHDOLOGY

Product modeling is important in the integration of information systems that are applied in current enterprises. To capture the product information within an enterprise and between the enterprises, united, robust and flexible data models are required. The object-oriented product modeling methods applied here have STEP/EXPRESS, XML and UML language.

### *A. The STEP Method*

STEP is an international product data standard to provide a complete, unambiguous, computer-interpretable definition of the physical and functional characteristics of a product throughout its lifecycle. The acronym "STEP" is the normal name given to the ISO standard ISO 10303, the Standard for the Exchange of Product data. As far back as 1984 the problems with the standards and specifications used for data exchange standard (IGES, SET, PDDI) had been identified and were well known. The previous data exchange like IGES can only facilitate the exchange of geometric information, and they are not sufficient for the information integration through the lifecycle. STEP is the first approach that introduces the idea of complete product model exchange into standards. More importantly, STEP can provide development methodology for modeling.

The initial release of the STEP standard (10303) was approved in March 1994, which is divided into a number of separate standards called 'parts'. The STEP 'parts' are organized into seven groups: (1) Description Methods (parts 11-19); (2) Implementation Methods (parts 21-29); (3) Conformance Testing Methodologies and Framework (parts31-39); (4) Integrated Generic Resources (parts41-49); (5) Integrated Application Resources (parts 101-199); (6) Application Protocols (parts 201-1199); (7) Abstract Test Suites (parts 1201-2199).

The STEP information model has a three-layer architecture consisting of the application layer, the logical layer, and the physical layer. The principal product representation of entities for all phases of product lifecycle is defined at the logical layer. At the application layer, a number of topical models specific to individual application are developed. The physical layer provides some methods including STEP file format, file exchange and database sharing, etc.

Those Integrated Generic Resources are written in the formal data description language EXPRESS. The syntax and relate information of EXPRESS are described in STEP part 11. EXPRESS is an object data descriptive language that classifies and constructs Integrated Resources by their data entities, attribute, rules, relationships, functions and constraints. EXPRESS is not a programming language. There is no EXPRESS compiler or an EXPRESS executable code. It is understandable by humans and computers. EXPRESS-G is a subset of the EXPRESS language, and it supports the graphical notations of scheme, entity, type and their relationship concepts.

### *B. Extensible Markup Language, XML*

The eXtensible Markup Language (XML) is becoming a standard for Internet data representation as a mark-up language and for data exchange over the Internet. It is a subset of Standard generalized Markup Language (SGML). XML is good for documents that are structured and long-term usage and, thus, very applicable for Internet applications.

In addition to its own standard, there are other XML related standards, such as Document Type Definition (DTD) for describing the schema of a structured document, eXtensible Style Language (XSL) for displaying and translating the document style, and eXtensible Link Language (XLL) for defining the linkages of document. Generally Speaking, XML has the following nine characteristics: (1) it can directly be applied on Internet; (2) it can support widely used software application; (3) it is compatible with SGML; (4) it is easy to develop related software for processing XML document; (5) the options for its functionalities should be minimized as much as possible; (6) its documents should be easy-to-read and clearly understood; (7) its design should be concise and careful; (8) its production should be quick; (9) its syntax should not be not unclear [8].

### *C. Unified Modeling Language, UML*

UML is used to specify a markup language by building precise, unambiguous, and complete models of the system. UML defines a set of basic diagrams that provide perspectives of the system under analysis or development. UML leads to a better understanding of the system by providing means of viewing the system from different perspectives. UML is made of three kinds of building blocks: thing, relationship, and diagrams. UML diagrams include Use Case diagrams, Class diagrams, Interaction (Sequence and Collaboration) diagrams, Activities diagrams, State diagrams, Deployment diagrams, etc.

There are four kinds of relationships between classes in a UML model: dependency, association, generalization, and realization.

UML is considered as a structured notation system understandable without too many explanations. For many team members of the collaborative team, it could be used as a common language providing a shared point of view between user and PLM implementers.

The utilization and understanding of this notation can be very complex, and only a subset of these diagrams is employed in our research, they are Use Cases, packages and class or objects.

## III. PRODUCT INFORMATION MODELING ARCHITECTURE

Based on our previous research progresses, in order to establish a united efficient reconfigurable product model, we separate the whole product life cycle into five stages: product requirement analysis, concept design, engineering design, manufacturing and service, and the corresponding product models are named as product Requirement model (R-model), product Concept design model (C-model), product Engineering design model (E-model), product Manufacturing model (M-model) and product Service model (S-model) respectively. Consequently, we name the overall lifecycle product model system as the RCEMS models (as shown in Fig. 1). The RCEMS models are described by the corresponding BOMs, configurations and documents, here the BOMs mean extensive. The mapping among the RCEMS models are explained in more detail elsewhere [9].

STEP, UML and XML are employed in establishing the product integrated model—the RCEMS.

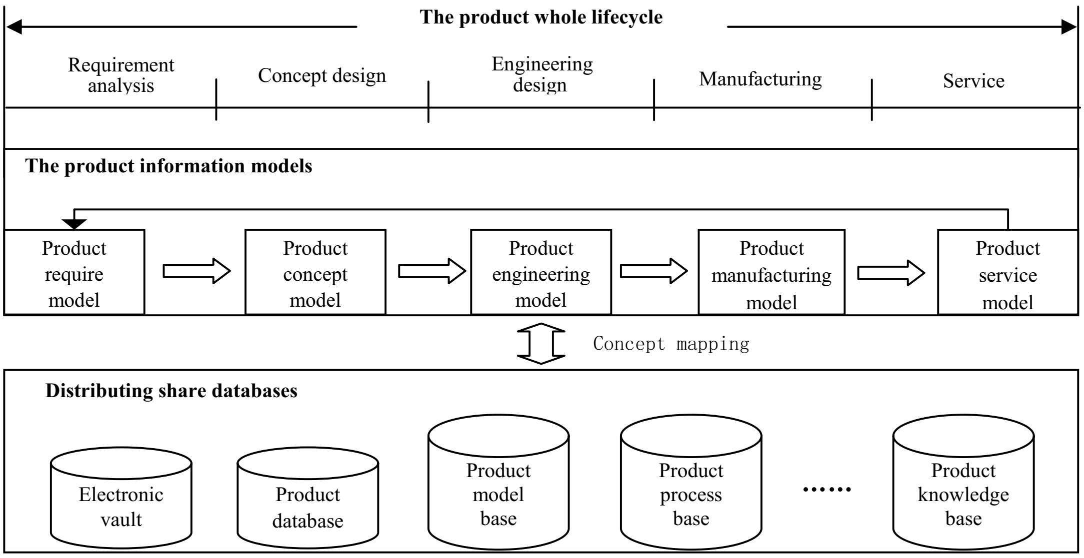


Fig. 1 The architecture of product information models.

## IV. COLLABORATIVE DESIGN

### A. *Collaborative Design Concept*

The necessity for teams of designers, engineers and manufacturers from various areas and diverse geographical locations to work together over networks has become paramount for companies to stay competitive or simply to survive. In the near future, it is likely to see that the success of product development teams will firstly depend upon the adaptability of existing design practices in the collaborative product development environment, and the related tools to support and facilitate design. Collaborative is being viewed as the next big wave after e-Commerce, digital commerce and several other variants that emerged in the last decade [10].

In simple terms, collaborative design is the process of designing a product by ways of associated groups operating throughout the life cycle of the product, which would include people from various departments such as design, manufacturing, assembly, test, quality and purchasing, as well as the suppliers and customers. Collaborative design environment enables remote designers to work together and to communicate among themselves on a common design project. The objectives of such a collaborative design team might include optimizing the mechanical functions of the product, minimizing the production or assembly costs, or ensuring that the product can be easily and economically serviced and maintained [11].

### B. *Collaborative Design Method*

In today's virtual enterprise, it is normal that design engineers are distributed all over the world, and thus it is important to share and exchange product data. Establishing a integrated product models for network manufacturing is the foundation to implement collaborative design.

The collaborative design method based on the RCEMS models is shown in Fig.2.

The R-model of a product is firstly established by multidisciplinary collaborative design group that consists of design engineers, manufacturing engineers, sellers and customers, etc., which reflecting customer requirements and/or market demands. The C-model of the product is further built based on the R-model by multidisciplinary collaborative design team including domain experts, design engineers, manufacturing engineers, sellers and customers, etc. According

PLM (Product overall Lifecycle Management) stores and manages complete information of all its products and related activities to ensure a collaborative and concurrent engineering environment, which facilitates easy and more efficient product development.

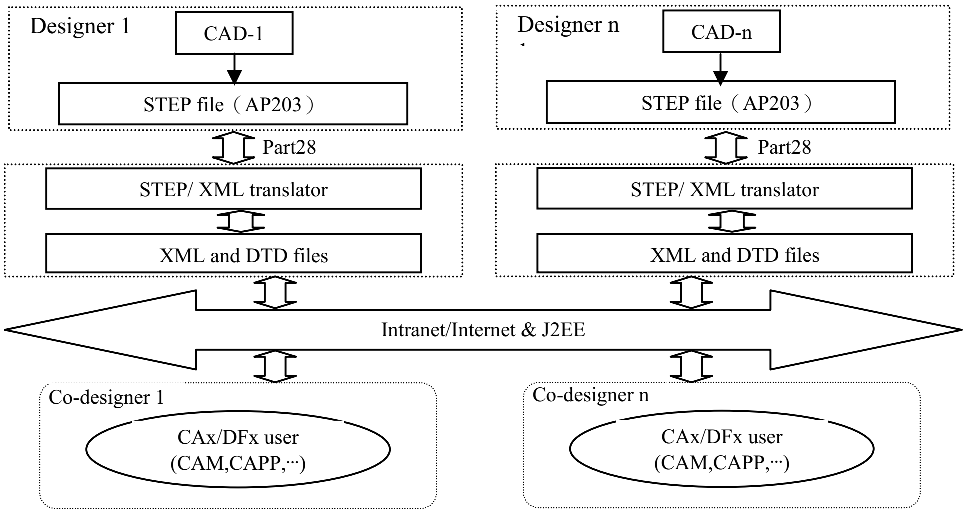


Fig. 2 Collaborative design method based on the RCEMS models.

to the product's C-model designers (1,…,n) and co-designers(1,…,n) collaborativly design the product over Intranet/ Internet by their own tasks. First, a designer begins their designs based on C-model using their own CAD tools, and the C-model is developed into the D-model. In this process product CAD models represented in STEP files obeying the STEP/AP203 are converted into the product data models represented in XML/DTD files by the STEP/XML translator according with STEP/part28, and so the product data model presented in XML/DTD files is easy transferred to the Internet. A co-designer (including manufacturing engineers, supply personnel and customers, etc.) submits their improved advices to the designer by the CAx tools. The other designers can also interoperate the D-model over Intranet/Internet, based on the J2EE standards. Consequently, through the previous collaborative design finished by multidisciplinary collaborative design team, the development time of a product is remarkably shortened.

## V. MAPPING AMONG DIFFERENT FORMATS

Data included in enterprise activities can be considered as business data or engineering data. Business data are involved in administrative activities such as order processing, and production planning. Engineering data define the specifications of products such as geometries, topologies, manufacturing information, and service manuals. Engineering data are usually in complex data types involved in engineering activities. As the whole enterprise is integrated via networks, the data exchange between business activities and engineering activities become common practices recently.

Today many companies have developed their own solutions for their specific needs. The translation relationship among different formats is valuable company's assets and usually include in programs, documents, or expert's personal knowledge. In most practices, the relationship is implemented into translators by some programming languages such as C/C++, Fortran etc. However, knowledge included in such executable program are difficult to understand and hard to reuse.

One way to represent the relationship in a high level is schema relationship. Because schema relationship is represented in the schema level, it is easier to understand and manage than the relationship in the data level. Some researchers have studied the mapping relationships between UML schema and STEP schema, or STEP schema and EDIFACT [3, 12-15]. We presented a schema relationship between UML schema, STEP schema and XML schema based on the former progresses. Fig. 3 shows the hierarchy of schema relationship and data translator. Once we have schema relationship between schemas (e.g., UML schema and STEP schema, STEP schema and XML schema), the data translator is automatically generated by a mapping interpreter. Therefore, establishing the mapping between UML schema, STEP schema and XML schema can sufficiently bring into play their own advantage in product modeling.

## VI. IMPLEMENTATION AND APPLICATION OF THE PLM PROTOTYPE SYSTEM

Based on J2EE, the proposed product integrated models, and the Web-based PLM architecture [16], we developed a

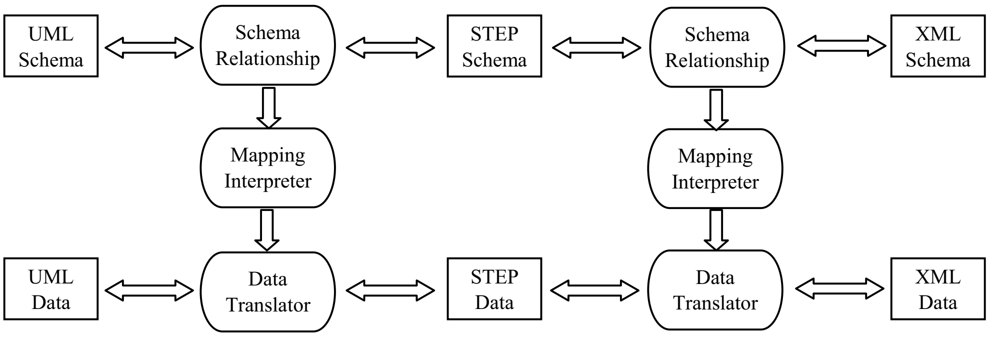


Fig. 3 The mapping relationship between different schemas.

PLM prototype system. The functions of the PLM system contain the system administration, the organization management, the product structure management, the document management, the process management, and the service management modules, etc. The sections that have been completed include the product information modeling, database management, the system administration, the organization management, and security handing.

STEP/EXPRESS, UML and XML are employed for product modelling during the whole phrase of lifecycle. The programming language used for the PLM system implementation is Java. The server end program is TOMCAT5.0. In addition, the J2EE technology standards, Jbuilder8.0 and SQL Server2000 are employed in the PLM system development.

The PLM system has been applied in the representative enterprise, and primary technical ideas are validated.

## VII. CONCLUSIONS AND FUTURE WORK

A product integrated models during the whole phases of lifecycle is proposed first in this paper. Based on the product integrated models, a multidisciplinary collaborative design method over Internet is discussed. STEP/EXPRESS, UML and XML are employed during the product modeling process. And a mapping relationship schema among the different data schema is presented for product data exchange. Finally, a PLM prototype system is implemented, and primary technical ideas are validated. The future works include: systemic deep researches about the mapping relationship between the different data schemas.

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