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ENGINEERING DESIGN IN INTEGRATED PRODUCT DEVELOPMENT
Design Methods that Work

ENHANCEMENT OF COLLABORATIVE PRODUCT DATA MANAGEMENT

Asko Riitahuhta

Tampere University of Technology
Box 589, 33101 Tampere
Finland

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Abstract: *The theory of technical systems emphasizes the requirement of describing a product as different hierarchical systems on three abstraction levels, process, organ and part structure. In this paper we show the meaning of different abstraction levels and we emphasize that especially organ structure and process structure should be utilized better in Product Data Management, PDM, systems. When a company produce multitechnical products the implementation project has often been long and difficult. We introduce in this paper how Product Structuring can enhance the PDM implementation. Especially in global business when product development is accomplished in a networking environment, process and organ structures should be shared between different parties. The intention is to coordinate the total development arena. The efficient utilization of modular structures and definition of network identity makes it possible to localize the products.*

1. INTRODUCTION

Companies in electronic or software business have reported big savings when they have utilised Product Data Management (PDM) Systems. However, when a company manufactures multitechnical products the PDM implementation project has often been long and difficult. In this paper we present experiences of industrial cooperation and some concepts how Product Structuring can enhance the PDM implementa-

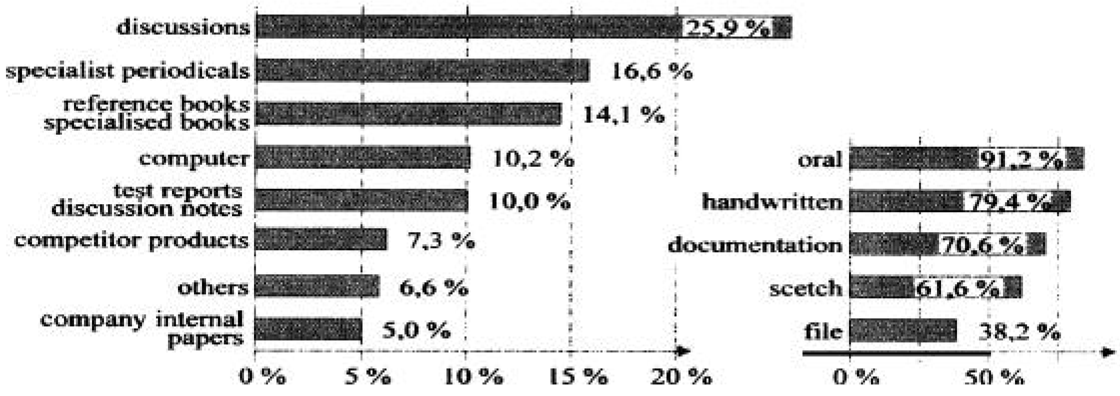

Fig. 1. Utilisation of different sources in collecting information, and communication during Product Development [1]

tion for better business.

Ehrlenspiel has stated [1] how complicated products are difficult objects for PDM-systems (figure 1). Designers prefer to communicate orally because they would ensure quality of information. A good PDM-system should eliminate the need for oral communications and discussions during the Product Life Cycle. A research group at Cambridge University has found that the response time of a PDM-system has to be under 20 seconds otherwise a designer would call for consulting a person.

2. FROM ENGINEERING CONFIGURATION TO PDM-SYSTEMS

It has often been presented that PDM-systems have three management levels: document, workflow and configuration. It has also been considered that above mentioned levels are steps and one has to start from the document management and go through workflow management to the highest configuration level. In 1980's the goal was to manage all the levels through Expert System technology.

In the middle of 1980's PDM or EDM (Electronic Data Management)-systems were started to integrate to CAD-systems. However, there were big efforts also to develop Expert Systems or Knowledge-Based Engineering Systems for capturing the product knowledge and creation of product variants e.g. configurations. Several types of software tools were developed. They were utilising, for example, the following representation methods: logic, rule, frame, object, procedure, and model.

The goal of active university research was to develop knowledge bases which were more useable, maintainable, and understandable for designers and other users. Following is the statement of SHARE-project led by Prof. L. Leifer at Stanford University [2]: *Increasingly, product development will involve teams of people from multiple organizations working together over networks, supported by computation and information services. The objective of SHARE is to provide the enabling technology that will support design engineers by allowing them to access helpful information over the network not typically available to a single user environment*. That goal is still valid for today's collaborative PDM-systems.

There also existed in Europe several Knowledge Systematisation projects. In Tampere University of Technology, we developed model-based Knowledge Based System, KBS, for a system product configuration. In the configuration development we have approached the following steps [3]:

1. We started to combine Knowledge Based Expert System, KBES, with CAD-system for configuring a product structure, product architecture and a product layout. Later on we combined Knowledge Base System and CAD with a relational database.

2. In big system products, the component selection is the key issue. In the development of a prototype for a big component selection system, we realised that the above-mentioned combination is not efficient enough. Therefore, we began to use Object-Oriented Data Base Management System, OODBMS. We have been successful in creating the Workflow for product configuration by utilising KBS, CAD, Documentation program and OODBMS.

Even though these configurators worked well they were too early concepts for industry. As being researchers we also started to study more fundamental things such as product structuring theories, modularisation etc. A new beginning with PDM-systems for us was when companies started to implement commercial PDM-systems for multitechnical products.

3. EXPERIENCES OF COMMERCIAL PDM-SYSTEMS

According to our survey, it seems that companies can implement a PDM-system in four months. However, in multitechnical products when a PDM-system implemented, Corporations can only benefit its utility or profitability after three years.

In the following nutshell are some findings from a globally operating company, which has 30% of worldwide markets:

<u>General background information</u>

?? PDM is a hub of engineering design systems
?? virtual enterprise: a platform might be designed and delivered from France, an engine from USA and a work process unit from Finland
?? many CAD-systems are utilized
?? number of items 220 000, number of new items in two years 10 000
?? after sales utilizes PDM-system (e-Commerce)

<u>Implementation schedule</u>

?? document management and dictionary in Finland –97
?? items management -97-98
?? system development efforts -00-01
?? change management -01-02
?? system implementation in two new manufacturing facilities (Finland and France) -01-02
?? system implementation in USA -02-03

<u>Open questions</u>

?? links to subcontractors' or suppliers' catalogs
?? no video conference connections between designers' workbenches.

<u>Survey in five large companies in 2002 shows a very similar picture as above presented:</u>

?? Implementation in 3 years
?? There is a gap between requirement phase and modularisation

?? PDM-tools do not support the functionality of collaborative product data management, all tools support a little bit different functionality

?? BOM [Bill of Material]-based PDM do not support reuse of data, Product Structure could be the base of reuse of product data.

4. DOMAIN THEORY

Companies have concentrated to data and information models for production purposes but they also have created other views. In this chapter our aim is to give theoretical frames for different views and structures. Figure 2 shows different views needed in Product Life Cycle. We concentrate to Product Model part.

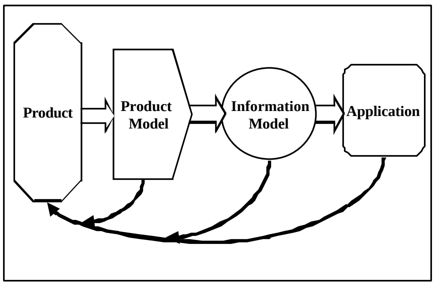

Fig. 2. Views of Product Modelling [3]

The result of design work in an industrial company is traditionally documented in the bill of materials and a set of drawings, i.e. the part structure is documented. Such a documentation reflects the production of the product, and it is difficult, based on the parts structure, to reason about the product's functionality and properties with respect to other product life phases; distribution, sales, use etc. Thus, we expect that an introduction of other types of product structures, which support reasoning about product functionality and properties will improve design work in industrial companies. In this section we will present the Domain Theory which offers three synthesis oriented product structure views: Transformation -, organ -, and part structure.

A theoretical basis aiming at explaining design has to take into account both the way in which human beings carry out design work and the artifact, i.e. the product, to be designed. Within the research community there does not exist general agreement upon a theory, which supports the synthesis of artifacts. However, in order to develop computer tools to support the engineering designer in designing products, a formal description of the constituent elements of the artifact is needed. The Domain Theory, [4, 5] offers such a description.

According to the Domain Theory the artifact to be designed can be seen as, (see Figure 3):

?? The technological principle of the transformation, which is the purpose of the machine, determines the effects, which are to be realized by the machine.

?? The organs realize the effects. Organs at a high system level can make it necessary to implement new transformations, which lead to second-order organs etc.

?? The machine parts materialize the organs. The necessary relationships between machine parts may lead to requirements for low level organs such as joining, connecting and support organs, which in turn lead to requirements for more machine parts.

The transformation system: The purpose of the machine is to transform its operands, materials, energy, and or information. Each individual step in the transformation is a process or operation, which alters one or more characteristics and properties of the operand. A transformation depends on a technology, i.e. an interaction between the operand and the necessary effects, e.g. forces and movements, which affect the operand.

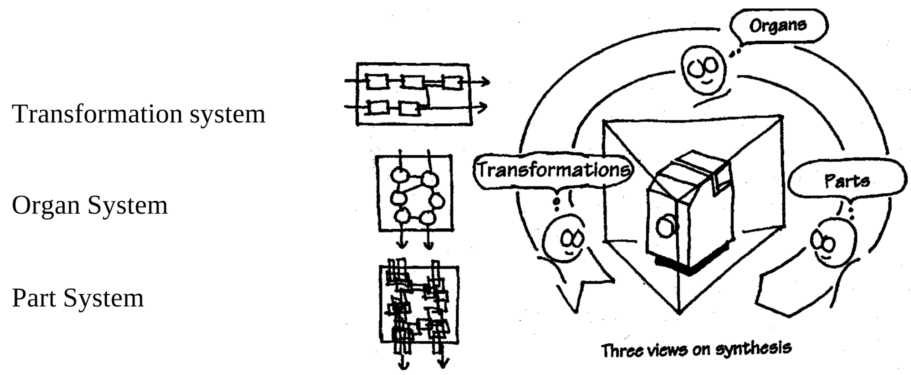

Fig. 3. The product to be synthesized can seen from three system views [4]

The transformations can be seen as a system where the system elements are the individual operations and where the relationships are the operands. Technical systems very often are an user operated. It is a necessity to describe both: an user and a technical system, Figure 4.

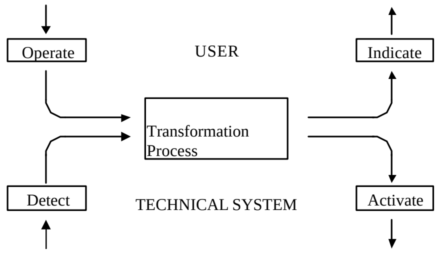

Fig. 4. Transformation Process realized by a user and a technical system [6]

The organ system: The active elements, which create the effects in the machine are the organs [7]. An organ may have three types of constituent. An interaction between several fields of material may constitute an organ, e.g. the interaction between the teeth of two gear wheels constitutes a gear as an organ. Secondly, a material volume may carry an organ, e.g. a shaft can be seen as an organ, which transmits force and moment. Thirdly, a volume bounded by material surfaces can be an organ, e.g. a cylinder volume constitutes an organ that in interaction with a piston may realize the function `create linear movement' of a linear actuator.

The organs can be seen as system elements with physical relationships between them.

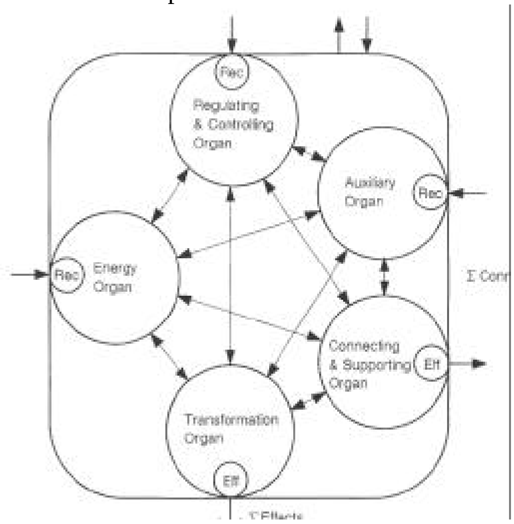

Fig. 5. The wholeness of five types of organs [7]

The part system: In the mechanical product the organs are distributed on the parts in such a way that the parts can be produced respecting the organ requirements. One organ will normally need several machine parts for its realization, while a machine part will often contribute to the realization of more than one organ. The characteristics of a machine part are: Form, dimension, material, surface quality, and tolerance. The machine parts can be seen as system elements, where the relationships between the parts are of type assembly relation based on position and forces.

5. IMPLEMENTATION OF THE DOMAIN THEORY

There are several means for transporting on land by using manpower. Roller skates are one means. The in-line skates are dominant, the sales of old type skates have dropped nearby to zero. Old type skates had only very limited use. In-line skates got new user areas. One of the manufacturers has 7 user groups, which they have named as follows ?Roller-blade, 1997?: Aggressive, Fitness, Regression, Women's, Hockey, Race and Kid's. Let us consider in-line skate as an example by using the domain theory as a theoretical framework. Figure 6 shows different structures.

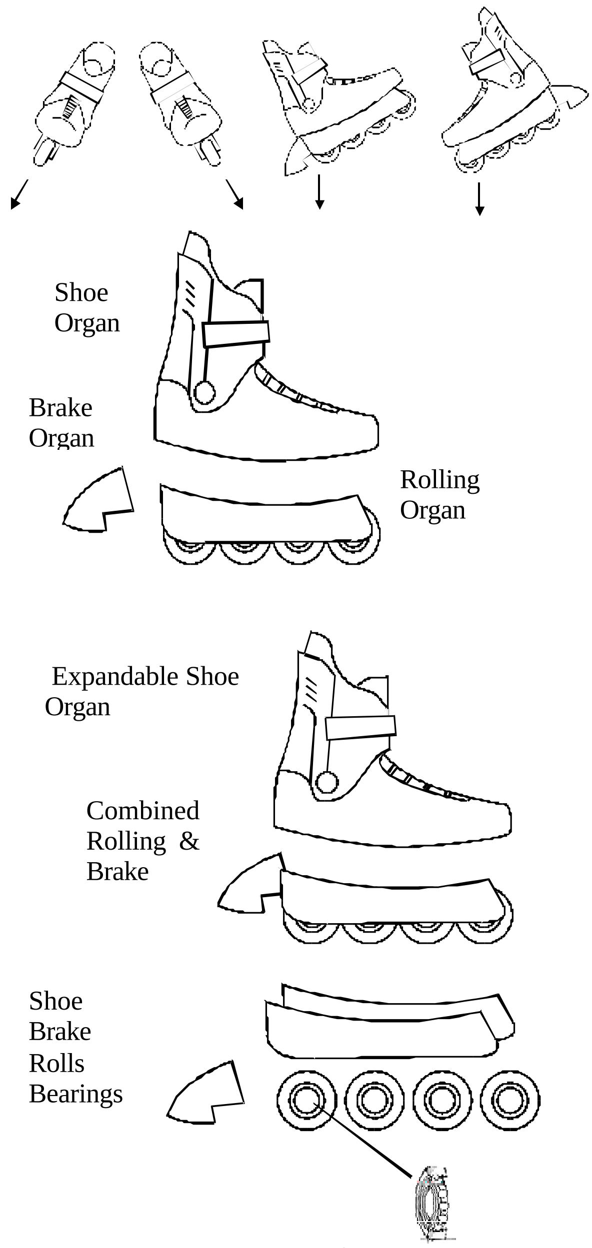

Fig. 6. Three domains of in-line skates

Roller elements compose a module, which is a function carrier and has function structure. However, the function structure is not alone enough powerful means for product development. When function structures are established, the next needed structures are organ structures. They make it possible to search for suitable working principles.

Functions of a user:
Put on protective gear, Skate forward, Skate backwards, Brake, Take off, Maintain, Store.
An example a more detailed function: Carry weight of a skater in different situation.
Static and dynamic situations: Two feet, one foot, gliding, jumping, shocks of a road.

Basic organ structure:
Shoe organ, Brake organ, and Rolling organ.

Advanced organ structure:
Expandaple shoe organ, Combined rolling and braking organ

Parts structure:
Shoe, Brake, Rolls, Bearings

From Figure 6 we can realise how well organised, hierarchical information it is possible to encapsulate to the structures of domain theory. We take two examples:

From figure 6 we can form different static and dynamic load cases for analysis purposes. It is possible to make a relation between function structures and analysis.

The use of the organ structures help us to create new R&D projects. E.g. we can take into consideration organ by organ, make questions and create optional answers. In-line skates techniques have been developed as follows:

?? Safety, simple to use braking system.
?? Elastic, step energy absorbing and discharging structure, which damps vibrations and shocks excited by a road.
?? Expandable shoe for children.

How the Domain Theory supports above-mentioned development projects. From the goal, process and function structure we see that a user's goal is a similar skating process as on ice. On ice the control and the braking is based on changes of pressure both along the blade of the skates and between the skates. These phenomena direct us to consider which connections could create between Rolling organ and Braking organ. In commercial solutions there is developed a mechanism, which operates when a braking foot is slided forward. The pressure of the rear cuff of the skate causes the brake to press down on the pavement.

The product analysis according to Domain theory directs us to search a solution by examining the connection between organs, but also developing organs themselves. We can use organs as free bodies in the Technical Mechanics. In the above-presented example the combination of rolling and braking organs directs to a module in the building structure.

The continuous improvement of product demands to perform the product analysis on the different Domain theory structure and their *hierarchical levels.*

Our institute with industrial companies has utilised Domain theory in the development of following systems and products:

?? New concept of Integrated Paper Production Mill
?? New concept for 4-axis Machining Center
?? Organs as a platform carriers in consumer electronics
?? Optimization of control system distribution.

These research cases show that the product structuring on three abstraction level works well and improve productivity.

6. SIZE RANGES AND PREFERRED NUMBER SERIES AS A MEANS TO ENHANCE MODULARISATION IN PRODUCT DEVELOPMENT

The topic modularization with focus on platforms, configuration and also innovation is very actual and important paradigm for Finnish globally operating corporations. Our research team has cooperated with companies on different focus areas of modularization. Today's interest is towards platforms and the combination of innovation processes to modularization.

During the last year we had 20 industrial related diploma thesis in modularization area. In some diploma thesis the productisation and the development of a mechanical structure has been a main goal. In these thesis we have found the demand for enhancing of structuring modular system. Pahl&Beitz /9/ have presented that modularization, size ranges and preferred numbers are the each others supporting wholeness. In 1980s and 1990s parametric programming in CAD-systems has been caused that the use of size ranges has lowered. Our hypothesis is that today when platform thinking is breaking through these two methods are becoming more and more important.

The strongest improvement of productivity has been reached when modularization, size ranges and DFMA-methods are combined. One case is in a generator case for wind mill.

7. CONCLUSION

The key issue in the implementation and application of computer tools to support development of multitechnical products in industrial practice is systemization of product knowledge and organization of development activities in relation to the company's business strategy. The balance made in this article shows from a design science viewpoint that there exist results, which explain the nature of the product to be designed. The Domain Theory and the classification of product structures constitute a framework in which product knowledge can be systematized. Based on the examples given, we expect that the positive effects of applying the framework to systematize the product knowledge of an industrial company when implementing computer tools will be measured by e.g predictable product quality, reduced lead time, and reuse of design solutions.

The framework for the systematization of product knowledge is not yet generally operational, i.e. there does not yet exist a method of how to develop and implement computer tools based on the framework. Thus, the authors foresee a number of implementation projects carried out in cooperation between industry and university. In such projects it will be the task of the industrial company to deliver product knowledge and change work processes, and it will be the task of the researchers to define the product knowledge in accordance with the framework and transform this knowledge into propel information models. Although these tasks are not trivial and difficult questions have to be answered, the authors believe that the positive effects will outweigh the costs.

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