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Managing product and production variety – a language workbench approach

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Abstract

Product platforms are commonly used in industries with complex products and high competition like the car and truck industry to allow a customer to order a product that satisfy its unique needs. A consequence of product variety is that manufacturing and assembly processes need to deal with this variety as well. If the variety is low and changes of the product occur infrequently then the variety may be handled by designing the production system for a small set of typical products. But as the variety increases and changes become frequent the necessity for integrated product and production information model is high, to partially solve this problem Product Life Cycle Management (PLM) systems aim at providing an integrated model to all categories of users, e.g. product designers, product preparation engineers, line builders and shop-floor workers. All users need to access the information in the platform and refine and modify the information to reflect new knowledge that has been acquired. Today, most often multiple systems are used where some systems may store information in a structured way but often unstructured text documents are also used. This easily results in redundant information models and automated analysis is not feasible or not event possible because of issues regarding cohesion and traceability of information. The contribution in this paper is to discuss how a new type of tool for building domain specific languages and editors using language workbench approach can be used to support the different user categories in their tasks working with variability of a product and production system while at the same time provide cohesion and traceability of information.

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1. Introduction

Product Life Cycle Management (PLM) [1] strategies aim to integrate information throughout a products life cycle from the imagination of the product to the design and realization of the product and information about the use and recycling of the product. A PLM system supports everyone in the organization, from purchasing, to product designers, to production preparation engineers, to shop-floor workers. In [2] requirements for PLM systems, in a workshop hosted by NIST (National Institute of Standards and Technology), are presented. The notion of *cohesion* and *traceability* of

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information is reported as being crucial for improved data management of PLM systems.

This paper is part of an ongoing EU FP7 project Know4Car [*] which aims at developing a knowledge-based collaborative platform of the design and deployment of manufacturing systems [3]. In this paper we discuss how a new type of tool called *Language Workbenches* can support cohesion and traceability of information in such a knowledge based system. We specifically focus on managing variety of the product and the production system.

Handling variability within the automotive industry [4] is a vital aspect. In today's competitive market the diversity in customer's need have resulted in a high level of variability in the products which have to be manufactured. As a result in the manufacturing industry there has been a shift from single products to product families and product platforms [5]. Within each product family there is a high degree of variability. Hence the type of information which the manufacturing industry has to work with is tightly coupled with variability. This variability has affected both the design of the product and the production process. It can be said that variability has affected the whole process platform [6], where the term process platform is used as a conceptual structure of producing a family of customer specific products.

When ordering a car or a truck, a customer might have it customized to meet the individual needs. While the car industry typically has a well-defined set of options that the customer can choose from, a truck is used in a wide range of environments and used to carry different type of loads. Consequently individual trucks from the same product family might have very different physical characteristics. Product platforms define a set of components and configuration rules that model how these components can be combined together accordingly. The product variability has consequences for the manufacturing and assembly processes [7], because they have to adapt to the characteristics of each unique order. If product variability is low, the production process might be adapted to solve each possible variant. However, in this paper products with high variability are considered, where it is not feasible to exhaustively enumerate all possible variants. This is typically the situation in the automotive and truck industry.

Building a new or modifying an existing manufacturing or assembly line is a costly and time-consuming process that needs to be supported by efficient tools. Various user roles like product designers, production preparation engineers, line builders and shop floor workers need support and tools to share knowledge in an efficient manner.

Variability during product design and the design and operation of the production systems influences many stakeholders. Product designers define and develop engineering solutions for product platforms and specify requirements and constraints in the platform e.g. allowed combinations of the components in the platform. Production preparation engineers together with line builders have to consider all possible product configurations that might be ordered by a customer, and need to develop a production system that is able to handle all possible variants of the product. The variability has consequences for both the distribution of operations between assembly cells, but also on the distribution of operations between shop-floor workers in the same cell. The variability of the product platform increases the complexity of analyzing the consequences of new or added information for the production system.

In [2] cohesion is defined to be knowledge of the interrelationships that exist between data and traceability to be the knowledge of origin or basis for believing in certain data. Different user categories that work with the information and knowledge for the product and production system prefer to represent the information in different ways, for example, the product designers and preparation engineers prefer to represent the parts and subassemblies in different ways. This difference in representation is because for the product design the focus is on the structure of the product while the assembly order is of importance to the product preparation engineer. Since the design and development of a product and the production systems will go through several cycles it is time consuming and error-prone to have multiple representation of the same information in the system. In [2] the properties, *associatively across views* and *logical consistency* are identified as two important properties of systems supporting cohesion and traceability. Associatively across views means the absence of knowledge that two conceptualization are used for the same purpose and also the absence of knowledge that two references refer to the same thing. Logical consistency is defined to be *type awareness*, *interpretation constraints* and *wellformedness conditions of the information*. Another important property is the traceability of the origin of belief, where an assumption that was true at some point might no longer be true and thus invalidating certain decisions that were made previously. Problems regarding cohesion and traceability of information will result in an inefficient process working with the information in the product and production system.

Domain specific languages (DSLs) [8, 9] are for end-users of a system, who are supposed to be domain experts but not experts on computer languages. DSLs might be textual or graphical or a hybrid of the two. DSLs support a concise and domain-specific notation for working with information within the domain. DSLs also benefit from many of advantages with general purpose programming languages as having a well-defined syntax and semantics. This allows DSLs to support the automated analysis and transformation of data. Importantly, DSLs provide extensive support for handling the conceptual and associative gap that was crucial in PLM systems, but also for dealing with logical consistency of the data. This is because in a DSL it is straightforward to make a distinction between a types and instances of parts. Also a DSL can easily enforce types and logical constraints that guarantee that the information is consistent and does not contain contradictions. In addition DSLs excel at modelling associations between information something which is useful for supporting traceability of information and decisions.

Language workbenches [8, 10] are tools that support development and use of DSLs. While most existing tools focus on pure textual languages, the two language

[*] www.know4car.eu