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Federative approach of interoperability at the design / manufacturing interface using ontologies

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Abstract : In the production enterprises, interoperability between information systems used is the key for a successful Product Lifecycle Management approach. Despite many research works, the preservation of the information flow along the product life is still problematical because of the scientific and technological locks existing. These locks are identified in this paper and a new federative approach of interoperability is proposed, based upon the use of ontologies and semantic web tools.

Key words : semantic interoperability, ontology, PLM, standards

1 Introduction

During the last decades, the production enterprises have changed their products and processes. The rise of product diversity, the collaborative and concurrent engineering, the externalization of the production are indeed usual in today's production. They aim at reducing the time-to-market and increasing the competitiveness; but raise the complexity of the product environment. Mastering the current complexity in production is a crucial key for maintaining the constant progress required.

The Product Lifecycle Management (PLM) is an approach to master the inherent complexity of product development among the whole product life (from the design to the recycling step), by "integrating and making available *all* of the information produced through *all* phases of a product's life cycle to *everyone* in an organization" [1]. A PLM approach requires *inter alia* to ensure interoperability between the different participants in product development and their specific information systems. However, it is well known in the literature that the existing lack of interoperability is actually an important brake on achieving a successful PLM strategy [2].

In this paper, the first section describes the interoperability and the product modeling issues at the design and manufacturing steps. Then section 3 raises the research problematic induced and exposes the proposed approach. Finally the section 4 concludes this work.

2 Problem statement

2.1 Design/Manufacturing information systems

In production enterprises, "the main need today is the communication of updated data from engineering to production management" [3]. The present work consequently focuses on the design/manufacturing interface.

The design information systems can be classified into three categories [4]: the authoring systems (that generate technical design data, like CAD systems), the product data management systems (PDM) and the design management systems (that enable collaborative work). The manufacturing systems can also be classified into three categories [5]: the Enterprise Resource Planning (ERP), the Manufacturing Execution Systems (MES) and the Advanced Planning Systems (APS). These diverse systems describe the product

in different specific ways, depending on their own needs. But they all have to collaborate and quickly et efficiently share information: interoperability is required.

2.2 Interoperability related definitions

Wegner [6] defines interoperability as "the ability of two systems (or more) to communicate, cooperate, exchange services and data, thus despite the differences in languages, implementations, executive environments and abstraction models". Therefore, ensuring interoperability proceeds in three levels: the technical, semantical and the organizational levels [7]. The present work especially focuses on the semantical level, that deals with preserving the semantic flow of information from any loss during the product lifecycle and ensuring good understanding of these information from each participant; while keeping the perspective of proposing the adapted technical solution.

There are three manners of achieving semantical interoperability [8] [9]: integration (all participants share a standard format), unification (a meta-level structure establishes semantic equivalence between the participants) and federation ("models must be dynamically accomodated rather than having a predetermined meta-model").

Most of the current works deals with unification approaches [10] [11] [12], since it is more agile and flexible than the integration approach, and because the current federative approaches based on ontologies alignment are not convincing for the moment [13]. Indeed, most of the time, the ontology alignment (that is global) is made from a set of correspondances between entities (that are local) from the different ontologies [14]. This paradox generates lacks in nowadays federative approaches of interoperability.

2.3 Information modeling

The interoperability between information systems optimizes the information exchange and is therefore crucial in a PLM approach. But an interoperable system is useless if the transported data are inefficiently extracted and stored. Less than 50% of Manufacturing Bill of Material (MBOM) are for instance stored into PDM, ERP or MES systems [3].

The production data are extracted and formalized *via* the specific product models at each step of the product lifecycle. The choice of the product model constricts the quantity and the quality of the extracted information. It also determines the formatting of the data. The product models used in actual unification approaches can be *ad hoc*, but are most of the time based on standards data models, using standard languages (for instance the STandard for the Exchange of Productdata (STEP)) and standard visualisation (for instance the Unified Modeling Language (UML)) [15]. These standards help to perform mapping between the information systems, but these mapping are built manually, providing a *static* description of the product, which is not compliant with actual enterprise needs for agility and flexibility. Contrariwise, semantic models "can enable entities to achieve reliable and efficient collaboration [by] inferring new knowledge, querying, retrieving and storing" [16]. They enable a federative approach of interoperability, bringing intelligence to the product information.

3 Research question

3.1 Problematic

The problem statement is resumed on the figure 1. The state of the art reveals a rising need of interoperability and information exchange due to the growing complexity and competition that production enterprises are facing. Information are available in the different product models and need to dynamically and intelligently circulate between the different systems. The litterature also shows that the main current need of interoperability relies at the design/manufacturing interface. The research question arised is therefore how providing federative interoperability between design and manufacturing systems. This means using ontologies and implies to dynamically model the semantic interactions between design and manufacturing.

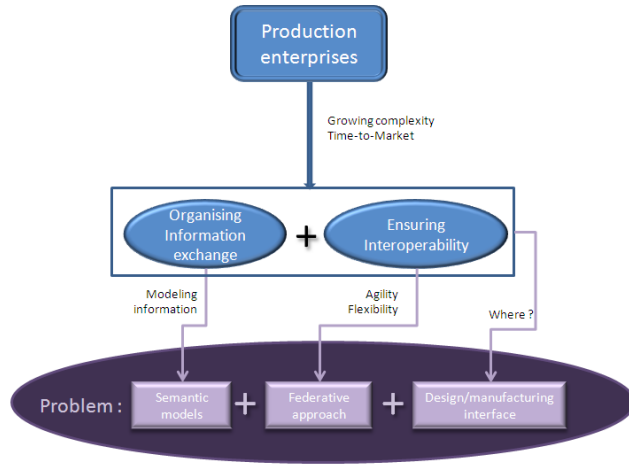


Figure 1: The need of federative interoperability in production enterprises

3.2 Ontologies for the PLM

The semantic models are based on the use of ontologies, than can be expressed into two standard languages: the Ontology Web Language (OWL) and the RDF graphs [17]. According to the usual definition, ontologies are a "formal, explicit specification of a shared conceptualization" [18]. As part of the semantic web technologies, ontologies are consequently a relevant tool for working on a federative approach of interoperability [19]. Recently, several works proposed product modeling based on ontologies, like the Open Assembly Model (OAM) [20], but also service modeling [21] and process modeling [22].

The OWL-DL language is a logic-based representation formalism creating an object oriented model. But as [16] revealed, OWL is not sufficient to contain the expressivity requirements for product modeling; domain specific rules, expressed in Semantic Web Rule Language (SWRL), must be added to the OWL-DL model.

3.3 EBOM/MBOM views

EBOM and MBOM representations are specific views of the design and manufacturing workflows, containing all the product information, but mostly implicitly. Even if they share a comun graphical representation (a tree-like structure), they describe very different features. The EBOM describes the virtual product whereas the MBOM carries the manufacturing process used by the Material Requirement Planning [23]. Expressing the meaning of the parent/child relationship in these BOMs, as well as the one of the items, are the key for explicitey modeling the design and manufacturing information.

3.4 Proposed approach for achieving a federative interoperability in the area of PLM

The scientific approach is described on figure 2. The idea is to propose a conceptualization *via* a simple and minimal product model, based on ontologies and rules. This model must be able to describe the design and manufacturing entities and the links between them. It is built according to the queries and reasoning demanded by the interactions between design and manufacturing. The prerequisite of this work is therefore to understand the specific viewpoints and needs of both design and manufacturing work, and how they interact together.

After extracting data from design and manufacturing specific models, this global model is then able to reason and infer data that are afterwards resited into the local views. Thus, the dynamic mapping between design and manufacturing are indirectly but completely achieved. The extracting data step will be based on the use of standards (see figure 2) that already exists at each level. For instance, OntoSTEP

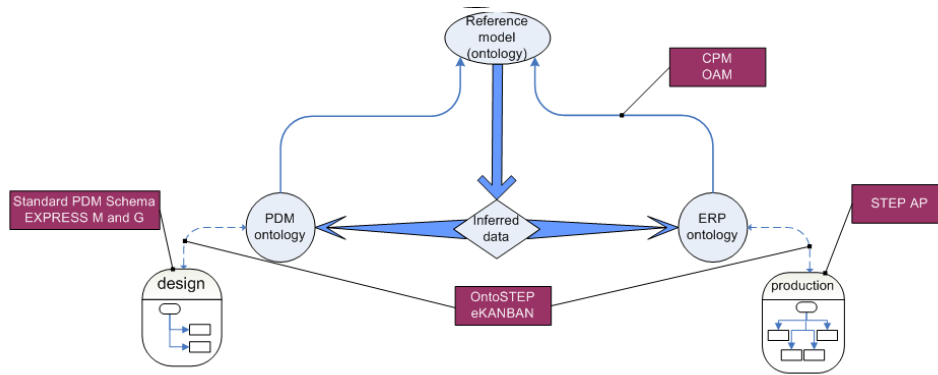


Figure 2: Proposed approach

and eKANBAN provide local ontologies for the design and manufacturing information, when EXPRESS and STEP AP modelize the design data and the manufacturing data.

We intend to pursue then the reflection by including to this product modeling the process too. In a global approach of interoperability, the establishment of this product/process link is indeed the main way to include knowledge to the information [24].

4 Conclusion

The present paper expresses through the state of the art the current need of interoperability between information systems in the Product Lifecycle Management. It also shows that the federative approach, based on the use of ontologies, and coupled with the definition of semantic models seems to be an effective way to answer the actual problems in production enterprises interoperability. Our research will first focus on the design/manufacturing interface, and aim at defining a global ontological product model. Thus, semantic correspondances between EBOM and MBOM would be indirectly but completely established. This semantical modeling will be completed with the proposition of a robust technical architecture and will be validated on a use case.

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