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► **To cite this version:**

Angela Tursi, Michele Dassisti, Hervé Panetto. Products information interoperability in manufacturing systems. Ottavo Convegno AITeM (Associazione Italiana Tecnologia Meccanica), Sep 2007, Montecatini Terme, Italy. pp.10. hal-00168536

HAL Id: hal-00168536

<https://hal.science/hal-00168536>

Submitted on 29 Aug 2007

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Products information interoperability in manufacturing systems

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Abstract

Information flows and products traceability are considered as tools to protect consumer safety. To meet traceability requirements, it is mandatory to find a system able to trace all relevant information related to the product lifecycle. This information is quite often scattered within organizations.

The heterogeneity of applications induces a sort of “Babel tower effect”, which causes traceability problems, leading systems to fail at collecting information from different and heterogeneous sources to effectively trace the product lifecycle. Generally speaking, this kind of problem falls within the umbrella of interoperability problems.

This paper postulates a different point of view to resolve these problems, the *product-driven point of view*, starting from the observation that the product is the common element perceived in all manufacturing operations and that added values are engraved on it unequivocally. The paper extends previous research activities by sketching a common information model, embedded in the product itself that stores all technical product data, with respect to the product traceability, during its lifecycle.

In order to express and share product information in a model, used by all applications of the enterprise, it is necessary to formalize and identify the concepts related to products technical data. This paper proposes to adopt a *Product Ontology*, based on existing standards, to support seamless enterprises systems interoperability and make easier information recovery easier for the products traceability.

Keywords: Interoperability, Traceability, Product Data Management, Ontology, Product Information

1 INTRODUCTION

Nowadays, information flows and products traceability are considered as tools to protect consumer safety. The first priority of product traceability is to protect the consumer and to ensure a fast product withdrawal or recall in case of incident. Mandatory for food logistic suppliers and vendors, traceability is now becoming a leading question in lots of industrial contexts and sectors [1].

To meet traceability requirements, it is mandatory to find a system able to trace all relevant information related to the product lifecycle (design, manufacturing, sales and use and disposal). This information is quite often scattered within organizations: it is a matter of the materials adopted, of the applications used to manage technical data (say, e.g., Product Data Management systems (PDM)), of the applications that manage business data (say, e.g., Enterprise Resource Planning (ERP)) and, finally, of the applications that manage manufacturing data (say, e.g., Manufacturing Execution Systems (MES)). Information is, to a certain extent, subjective since it is strictly related to the operators' knowledge and experiences.

The heterogeneity of applications managing information (ERP, PDM, MES ...), of users transforming, using and producing information (different operators) and of domains of pertinence of the same information (business or manufacturing) might bring to difficulties in information recovery, leading traceability systems to fail at collecting information from different and heterogeneous sources to effectively trace the products lifecycle.

The evident need is thus to manage heterogeneous information coming from different sources to achieve a unique view, allowing a common comprehension: such a problem can be defined as an interoperability problem.

Generally speaking, interoperability can be defined as that intrinsic characteristic of a generic entity (organization, system, process, model ...) allowing its interaction with other entities - to a different extent of simplicity - to co-working purposes, within a definite interval of time. Another possible definition of interoperability is «*the ability of two or more systems or components to exchange information and to use the information that has been exchanged*» [2].

This paper postulates a different point of view to face interoperability problems: the *product-driven point of view* [3]. Starting from the observation that the product is the common element perceived in all manufacturing operations and that added values are engraved on it unequivocally, the approach is based on sketching a common information model, to be embedded in the product itself. The model should serve to store all technical product data, with respect to the product traceability, during product lifecycle, providing a mapping from and to enterprise systems, as well as ensuring and improving the interoperability between enterprise systems.

In order to express and share product information, it is necessary to formalize and identify the concepts related to products within an information model that has to be shared by all applications of the enterprise. This paper sketches the specification of a *Product Ontology* for the representation of domain's knowledge, in order to ensure a non ambiguous understanding of objects and concepts related to the product.

An ontology consists of a vocabulary along with some specification of the meaning or semantics of the terminology within that vocabulary: ontology can support interoperability by providing a common vocabulary with a shared semantics [4].

The thesis sustained here is that it is possible in principle to build an "ontological reference model" centred on the product, in order to facilitate seamless enterprise systems interoperability, in order to make easier information recovery for the product traceability.

Standardisation initiatives in the frame of ISO (e.g. ISO 10303) and IEC (e.g. IEC 62264) try to face the interoperability problem by formalising the knowledge related to products technical data, modelling the definition of products information. These approaches suffer of the prescriptive nature of the approach, forcing users to translate information in a top-down fashion. The new bottom-up approach proposed in the paper, funded on the existing standards, provides mappings amongst different enterprise applications, either belonging to a single enterprise or present in a networked configuration, with respect to products life cycle.

The shape of the paper is as follows: the paragraph 2 describes the context and the problem faced in this paper; the paragraph 3 introduces standards initiatives, used as a base for defining the product information model and particularly the STEP PDM modules: the work on it will be explained in a sub-paragraph; finally in the paragraph 5 future research activities and conclusions are presented.

2 INTEROPERABILITY PROBLEM

Heterogeneous applications adopted for the operation of enterprise, either at business or at manufacturing levels, need to share information to cooperate: this can be critical to the whole enterprise performance. Ensuring product traceability during its lifecycle is a stringent constraint to this purpose.

Different applications may store, process and communicate information in different ways, according to the scopes for which they were collected and they are used. Each enterprise application adopts its own information repository, referring to a Reference Information Model, RIM (Fig.1). A RIM specifies the structure and embeds the semantics of the information treated, with respect to the scope of the application [5]. Each enterprise application retrieves information from its repositories, according to the specific need during its operations and a negative effect may result in the case of exchange with different applications: the translation required can bring to significant loss of information, due to several causes (say, misinterpretation, misunderstanding,...) and this may have impact on its effectiveness.

Problems, then, can occur when there is a need to exchange information between enterprise applications. Firstly, a problem of misunderstanding, due to different view points for which each application has been developed: there is not an univocal way to express the same information. For example, in ERP application, the term *resource* refers indifferently to human and to machine resources, while in MES the term *equipment* refers to machine resources and the term *personnel* refers to human resources. Consequently, a risk of loss of information semantics may arise when effectively exchanging between heterogeneous systems.

The *product-driven point of view*, proposed in the paper to overcome problems arising from the heterogeneity of applications, lie on the idea that the product is perceived in same way by all users independently from the heterogeneous sources and of the manufacturing operation. The product, along its life cycle, is the reference object from which all applications base their specific view.

The product, which evolves through time (in a diachronic way) along its lifecycle, represents a common Reference Information Model, able to support information exchange between the product views and the many applications that refer to it, providing effective mappings from and to the enterprise applications data. This model is also good to store and to record traceability information.

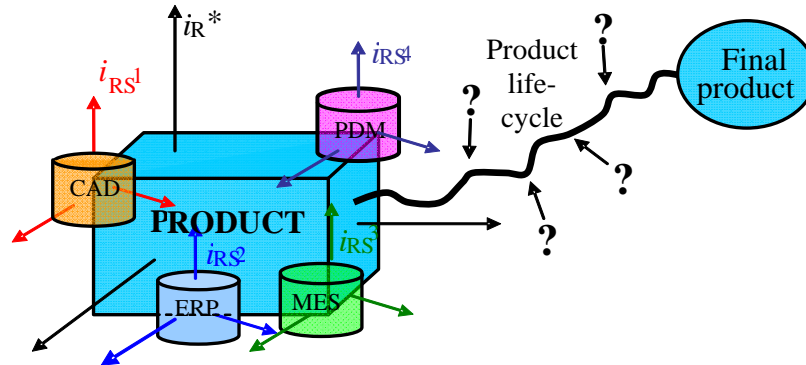


Figure 1. Enterprise applications RIMs and product-driven point of view

Provided that an ontology is an *explicit specification of a shared conceptualization* [6], the representation of domain's knowledge should be based on those objective characteristics of the product which cannot be misinterpreted or misunderstood.

The key point of the discussion will thus be first which contents and second how to formalise such *Product Ontology*, to achieve an comprehensive and shared view. At the same time, due to the formalization of the semantics of objects, the *Product Ontology* will allow accumulating on it that information specific of each application, descending from those modelling concepts and their dynamic behaviour adopted to express and to share knowledge.

Standardisation initiatives, such as ISO/TC 10303 and IEC 62264, will serve as basis to capture the first common features of information to answer the problem of managing heterogeneous information; formalisation efforts there provided will simplify the job of designing and building the *Product Ontology*.

We propose, then, to start the work by studying standardisation initiatives, such as ISO/TC 10303 and IEC 62264, allowing a unique comprehension of product technical data, from the perspective of these standards. Once these standards will be deeply analysed and when common concepts will be identified, we will be able to achieve a first draft of ontology. Not only common concepts will be identified but also the relevant ones for a *Product Ontology*. Secondly, we will integrate the obtained results with significant concepts extracted from enterprise reference information models, which we intend to consider, such as PDM, ERP and MES (Fig. 2).

Starting from the product view concept and taking into account standardization works, this paper traces and begins a research roadmap on this topic, to explore the

possibility to make enterprise interoperable on the basis of product-centred information view.

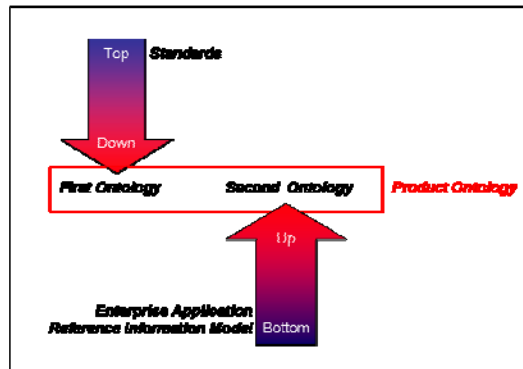


Figure 2. Steps to obtain Product Ontology

3 STANDARDISATION INITIATIVES

Information interoperability asks for common shared approaches: in fact, interesting standardisation initiatives already exist, such as the ISO 10303 technical specifications [7] and the IEC 62264 set of standards [8]. They try to solve the problem of managing heterogeneous information coming from different systems by formalising the knowledge related to products technical data. Both these standards are related to Product Data Management at the business and the manufacturing levels of enterprises (B2M). In the following sub-paragraph a short review of ISO/TS 10303 standard will be done.

3.1 ISO 10303 Technical specifications

ISO has been pushing forward the development of standards and models to foster the exchange of information related to goods and services (ISO, 2005). Efforts like ISO 10303 STEP – STandard for the Exchange of Product model data – have tried to deal with the issues of integration and interoperability problem. STEP represents the standard for the computer-interpretable representation of product information and for the exchange of product data. It aims to provide a neutral mechanism capable of describing products throughout their lifecycle.

Nowadays, STEP has been recognized as appropriate to help in the integration of manufacturing systems in industries such as automotive, aircraft, shipbuilding, furniture, building and construction, gas and oil.

A significant solution for PDM (Product Data Management) data exchange is the Unified PDM Schema, which is a basic specification for the exchange of administrative

product definition data. It has been created by unifying all PDM data between all existing STEP Application Protocols, and allows the exchange of information that is stored in PDM systems. This information typically forms the metadata for any product. In order to deal with the increasing demands on product models exchange, the standard has specified a set of STEP reusable modules related to PDM. These modules are now published as technical specifications (TS) and concern all related information attached or describing products technical data such as product structure, configuration control, persons and organisations, etc. PDM systems maintain a single copy of the product master data in a secure vault; the data are then distributed to those departments requiring them: modified, updated design data are then resaved in the vault. Data integration ensures that the information describing product design, manufacturing and life cycle support is defined only once; STEP data integration eliminates redundancy and the problems caused by redundant information.

STEP uses the EXPRESS language for describing data type, constraints on data type and relationship between data type. However, Application Protocols are required to contain a representation of the information in both EXPRESS and EXPRESS-G. EXPRESS-G is a diagramming technique supporting a subset of EXPRESS language.

4. ELEMENT FOR THE DESIGN OF A PRODUCT ONTOLOGY

The STEP PDM Schema is a reference information model for the exchange of a central, common subset of data to be managed within a PDM system. PDM systems are capable to integrate and manage all those applications, information and processes that define a product during its lifecycle, from design to manufacture up to end-user support. Typical product-related information includes several elements; to cite a few: geometrical features, engineering drawings, project plans, part files, assembly diagrams, product specifications, machine-tool programs, analysis results, correspondence, bills of material, engineering change orders [9].

The approach proposed in the paper starts from STEP PDM Schema, by finding the commonalities with IEC 62264 through matching and mapping activity. By using the UML Class Diagram formalism (Fig. 3) as a common conceptual language to make explicit commonalities between modules and then finding the common product features, it is possible to derive useful hints to our scope. This phase of the research was necessary to find a sort of common minimum denominator to derive a sound product ontology not from scratch.

In this paper we comment the main output of this mapping process focussing on STEP PDM modules: further steps of our research activities will follow in other papers later on. The figures 4 e 5 show some standard modules in UML Class Diagram formalism [10], where the first one is the model concerned to the generic enterprise activities performed on a product, while the second one is concerned to the technical and geometrical product characteristics. For instance, figure 4 shows the way work requests are processed and how these result in work orders that provide specify engineering activities to address issues raised .by the work order The work order thus

describes how a particular request for work is addressed and incorporated through appropriate activities: every work order has a reference to the activity method, that identifies the procedure describing how it is to be carried out. An activity may be associated with a information of status, describing its level of completion, as well as with the items that are the input or the result of an engineering activity controlled by the work order. An activity method and an activity can have properties, which have their own representation. By means of the activity properties it is possible to characterize technological activities. Figure 3 shows how it is possible to assign technological properties to objects, such as products or their components (Property_assignment_select). Each property has a representation, expressed in numerical values with dimensional unit specification.

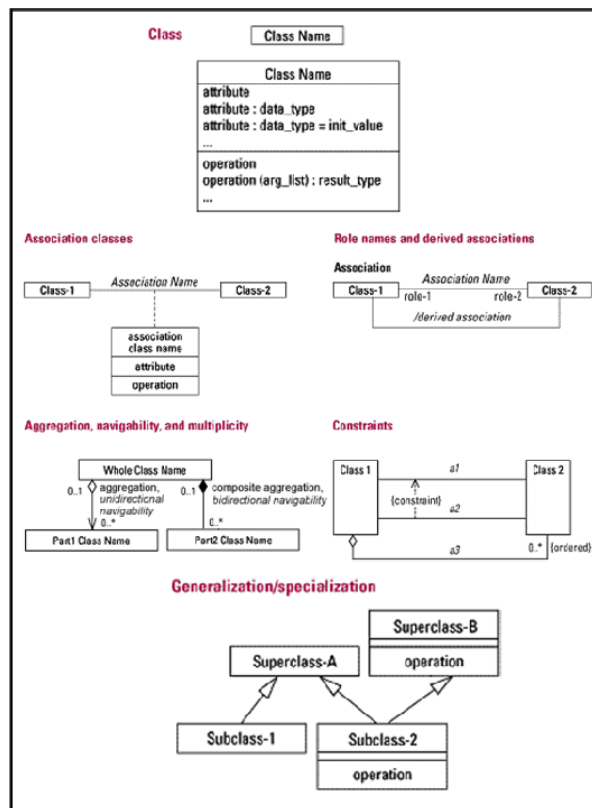


Figure 3. The UML Class Diagram formalism

UML language allowed to show how the standard is able to represent technical data related to product and then how it may be helpful to our Product Ontology, which is based on model product information during its lifecycle.

4.1 Application test case

After translating STEP PDM modules and then the IEC 62264, the next research step was to instantiate the obtained models in a real production system, as a validation process of the approach. This further step will allow to clarify the knowledge explicated as well as to discover some common points between the two standards. This step is to provide a clear view about the use of different terms to represent the same concepts or the use of the same term to represent very different concepts.

The industrial production system analysed was provided by a local technical centre: the AIPL-PRIMECA (*Atelier Inter-établissements de Productique Lorrain*) [11], in which 4 types of base part from a products family are manufactured and then assembled in order to compose 6 types of product.

Initially taking into account STEP PDM modules and IEC 62264 as base of the *Product Ontology*, other standardisation initiatives can be considered during the development of the work, in order to have a model that records the full traceability during product lifecycle.

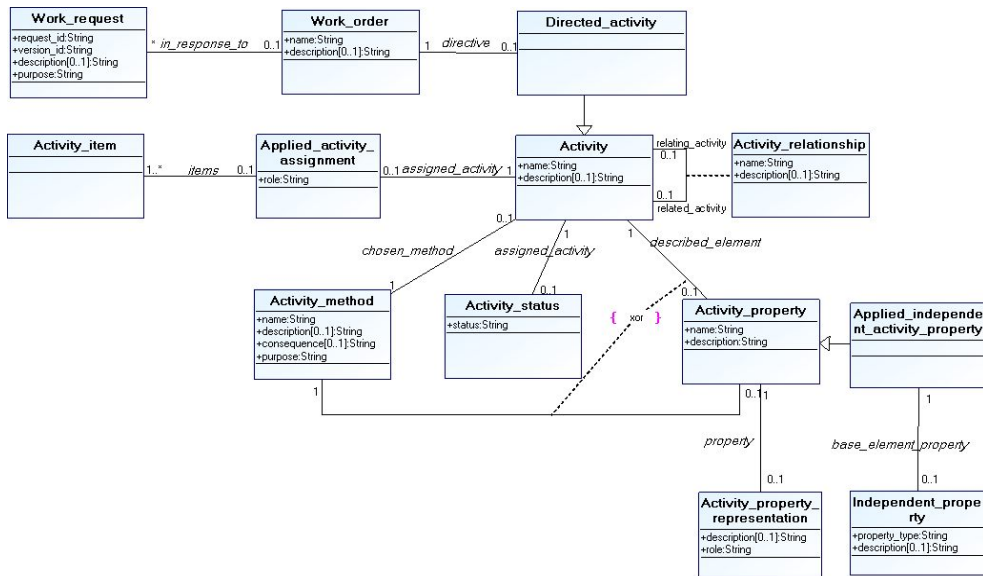


Figure 4. An extract of the conceptualized STEP PDM modules

The final objective of this research step is to validate the matching and mapping between the cited standards models, namely IEC 62264 and STEP PDM modules, in order to extract product related common concepts and consider them in our ontology. Specific standard concepts can be taken into account if considered useful for the

model. The ontology will be formalized through Description Logic (for ex. DL-Lite) [12], and verified by means of tools for building domain ontologies, such as *Protégé* [13].

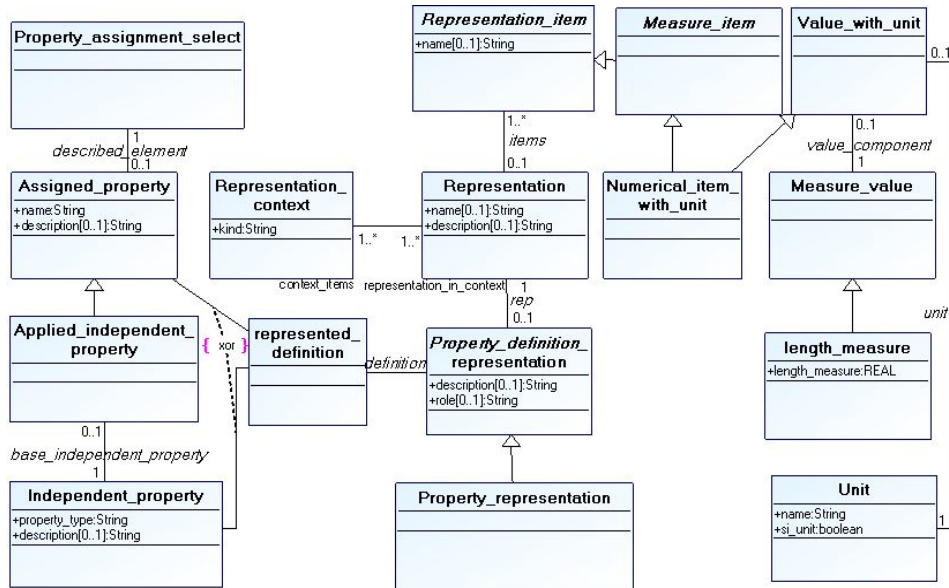


Figure 5. An extract of the conceptualized STEP PDM modules

5. CONCLUSION AND FUTURE RESEARCH

Starting from the idea that the product is the common reference element for many enterprise applications, and it has features perceived in the same way by most manufacturing operators, we believe on the postulate that it is possible to consider the product as a support to assure interoperability to systems, as far as the form used to embed knowledge about itself is adequate.

Information “engraved” on the product has to be structured in a common formal model, to provide mappings from and to the enterprise applications data, with respect to its life cycle: this is, here, referred to as *Product Ontology*.

The proposed approach is basically a bottom-up one, due also to the formalisation of knowledge and skill adopted and the semantics used to model concepts.

The future research will continue discovering the concepts coming from existing standards (not only those taken into account in this paper) in order to define the *Product Ontology*, able to assure full traceability of product lifecycle. The last step will be to refine the first model through the integration of the concepts identified into enterprise application RIMs.

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