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Facet-based approach for the management of information multi points-of-view in product modeling

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ABSTRACT
This paper presents a novel approach describing a framework that supports information representation and management along the product lifecycle. The aim is to provide a conceptual basis to build a multi-representation manager model which is useful for handling information sharing and interaction between experts from various domains, during the collaborative design project. The framework is based on the concept of facet that represents an elementary knowledge fragment of the product, as a combination of different information sources that are: product definition, business information, systems decomposition, and a temporal scale represented by the product lifecycle. The use of the facet concept for the integration of different points-of-view is described from a data modeling perspective.

KEYWORDS
Points-of-view; multi-representation; knowledge management; digital mock-ups

1. Introduction

Addressing the market needs, in a very strong competitive environment, is a serious challenge for companies nowadays. Manufactured products are more and more complex, involving expert knowledge and information from different domains and businesses. In order to design and manufacture products as quickly as possible, it is necessary to integrate business experts' knowledge earlier in the design process to make fast and robust decisions, controlling time, and thus controlling costs indirectly.

This was the purpose of the different research works conducted on Concurrent Engineering and Integrated Product Development (CE/IPD). As stated in [17], concurrent engineering means the use of multi-functional development teams designed to break down traditional communication barriers between functional groups such as product design, engineering, manufacturing, marketing and purchasing, and thus improving collaboration between teams. It requires a facilitated communication between teams in order to integrate their separate efforts into a well-designed system. This results in the control of the whole product development activity time, and consequently the control of costs. Therefore, eliminating the barriers and improving communication between the different business teams improves the performance of the product development activity. This results in a better collaboration between development teams, by integrating different business perspectives regarding the product, and working as a whole.

Concurrent Engineering and Integrated Product Development allows the integration of different business perspectives regarding the product in a concurrent manner. DfX (Design for X) emphasizes the consideration of design goals and related constraints in the early design stage, and allows the rationalization of services, associated processes, and systems. Using DfX and CE effectively, can improve cycle times, cost, and quality at the same time [25]. In other words, using DfX methods allows the integration of business information and knowledge exhaustively in the early stages of design. This business information integration is done by integrating different sets of constraints and goals related to each DfX (design for quality, design for manufacturing, etc.). Therefore the application of DfX methods in a PLM (Product Lifecycle Management) environment requires (1) the integration of several business models that take into consideration the various sets of constraints already gathered by DfXs (Design for manufacturing, design for assembly) at the same time, and (2) integrate them in a concurrent manner by proposing a set of interrelated models. Thus, the large number of models (at least one for each business activity) is going to increase the complexity of the global system in two possible ways: the first one concerns the need of strong interoperability

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between these models, the second one is the management of huge quantities and variety of information and data in a consistent way.

Otherwise, each model is going to constitute a basis for a specialized application which encourages the containment of information in silos, and makes communication with other business groups difficult. As a consequence, several conflicts and inconsistencies emerging from different design constraints, can appear on some common values of parameters (i.e. dimensions of two interfaced parts designed by separate teams). The concerned designers should work collaboratively to resolve these conflicts and ensure the consistency of the integrated solution.

Regarding interoperability, as stated in [3], it is the ability for two systems to understand one another and to use functionality of one another. Generally, three main scopes of interoperability are distinguished with different terms and definitions: 1) Conceptual interoperability that concerns the definition of common semantic or mapping mechanisms supporting the communication between knowledge and information models; 2) Organizational interoperability, which focuses on the connection between business processes; And 3) technical interoperability that deals with technological issues to support data exchange between software applications [24]. What can be of interest, is to decrease the complexity of semantic interoperability between intermediate models without changing the structure of the PLM environment, by taking into consideration the different experts' perspectives resulting from the integration of DfX along the design process.

Integrated design tools were developed and are available in order to reuse existing knowledge and information, elaborate solution concepts, and represent them. In this context, the Digital Mock-up (DMU) is still playing a central role in the product development process, in other words the central and principal reference for the experts. Despite the fact that it represents a collaboration axis from a conceptual point-of-view, the implementation of different proprietary tools (which are based on different business models) ensures interoperability only to a certain extent (use of neutral export formats such as STEP in order to exchange geometrical information regarding the product). This results in a very narrow point-of-view, on which domain experts reconstruct representations relevant to their business processes, by searching for already existing information which is not necessarily communicated, resulting in additional work of information traceability recovering.

Thus, a good way to address this lack of information is that, starting from a common product information artefact every expert should have a specific representation of information elements and reflecting his knowledge and adapted to it, by giving the right information at the right time during the right process, and at the same time, increase collaboration with other experts, and this results in offering different information representations specific for each context of use, based on a common model.

Often, multi-representation which is managed using a tree form, requires the definition of a hierarchy of different representations available using the concept of reference configuration. However the current frameworks still focus on the management of multi-representation according to one specific perspective only (i.e. integration of business views: simulation, design, etc.). Even if such management facilities give an important advantage, this is not enough to handle the complexity of the multi-representation problem resulting from the interconnection of all these perspectives.

In this paper is proposed an approach allowing the coexistence of different representations of the same product, in an independent, flexible and extensible way, based on the concept of "facet". This approach is based on a strong literature survey covering different perspectives generally considered for the representation of product knowledge.

The concept of facet is introduced in this paper as a product knowledge fragment resulting from the integration of a set of points-of-view taken by the business experts at one moment of the product development phase. For their technical tasks, engineers manipulate extrinsic as well as intrinsic product information and knowledge. This results in the use of product knowledge, business knowledge, systems decomposition knowledge, and product lifecycle knowledge. These are the four perspectives from which are extracted different points-of-view that are going to be exploited in order to build facets.

A Facet is not just going to gather information in order to represent it to the engineer who needs it, but rather connect the most pertinent information, to a specific context to build useful contextual knowledge for the designer to fulfil his technical and collaborative activities. This results in the management of information entities at different levels, in each point-of-view taken into consideration. For this purpose, a "facet management model" is proposed in order to be used to manage the different points of view related to the four perspectives presented before, and represent the right information, at the right time, to the right person. This model is going to interface dynamically the different models that embody the points of view, in other words, product model, business models, system decomposition model, and lifecycle model.

This paper is articulated in 5 different sections. The next section presents a general survey about the main perspectives currently used to manage the concepts of points-of-view: product perspective, business perspective, systems' decomposition perspective and product lifecycle perspective. In section 3 the approach is presented in detail with some examples of facets, and then the points-of-view management model is presented and explained. In section 4 a case study is detailed in order to present a concrete situation where the application of the facets decomposition approach would be effective. Finally, we discuss the challenges brought by this framework and conclude the paper with future works and perspectives.

2. State of the art

The definition of points of view varies from one group to another. Some groups see them as a limitation on what the user can legally or contractually see and observe. Some others consider them as separating information into silos, which corresponds to particular expertise knowledge. In this article, the point of view is considered as a set of information extracted from a global product data model, which gathers product information and knowledge which is relevant in the product's lifecycle. It can also be considered as an enlargement using specific informational entities selected in order to obtain a subassembly of shared information which is specific. It is a set of entities with a chosen level of granularity and context specific. In other words, a model containing global information about the product, considered as a reference set of information, from which we could extract sub-sets of information and data which enables the construction of points of view.

It is possible to predefine points of view, such as the ones in enterprise business modeling (MoDAF and ToGAF [6]). Their goal is to support the descending construction of information (top down approach), in a way that each point of view is relatively independent from the others. The work consists on the isolation of the points of view, which define frontiers without describing information transformation rules between each point of view couple. However, since the business knowledge and expertise is rarely static, and the future need regarding reused information and knowledge is not known, points of view that have been predefined could rapidly become obsolete, since it is related to a well-defined context, and thus could not fit the design activity. Thus, providing a points of view construction process is, more interesting than only providing rigid points of view.

This way, points of view are not considered as the transformation of an existing information, nor the creation of new information, but rather as a way of presenting a complete coherent set of information, by selecting only the ones that are relevant to the context and goal of the design. Thus, the construction of a point of view is essentially an information selection process (Fig. 1.). Consistency is then carried out by the global set of information relative to the data and information model (in our case the global model), common to all the points of view.

The advantage of using a single model as explained in [26] is that modifications made on a sub-model are reflected in the other sub-models. Consequently, the

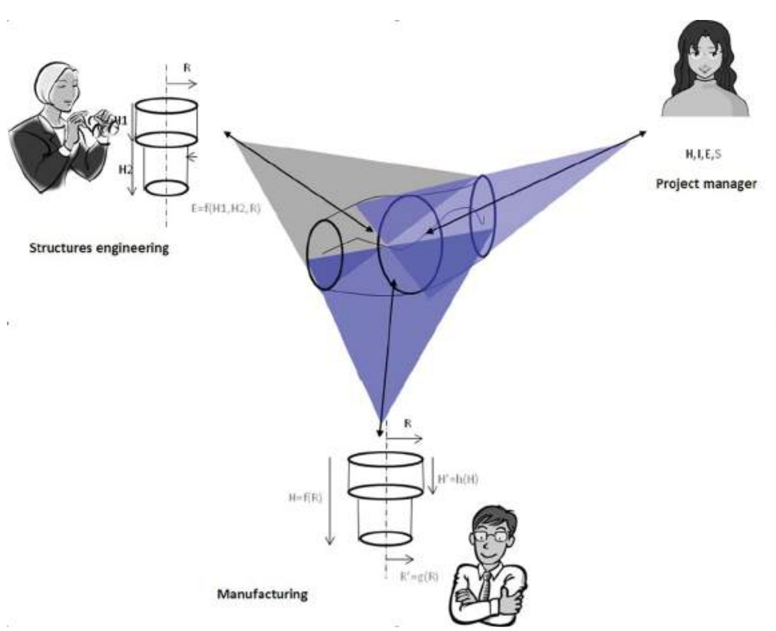

Figure 1. Points of view defined as a view, and selection of information from a common set.

problems of inconsistency due to the division of data between models are avoided [18, 20]. The principal interest of this approach is that there is a unique model to manage which facilitates the exchanges management and information sharing But at the same time, one of the drawbacks that one can find in the use of a global model is that it leads to a static product representation because the models handled by the various actors are fixed and do not vary at the same time as the product representation [7].

2.1. CAD & PDM/PLM multi-representation

Each expert needs a representation of the product and its related information and knowledge. In this way, geometric models evolved to integrate more and more domain knowledge, especially through knowledge management modules. PDM/PLM tools (Product Data Management) enable collaboration and co-construction of knowledge. Then, allow the establishment of shared, parameterized and scalable models, integrating more and more information about physical behaviour.

The data management tools (PDM/PLM), enables the management of the evolving models through the designing process, the management of the diversity of the product, and the multi-representation using the configuration concept. It answers simultaneously the problems of design process dynamic management (effectiveness, phasing), product diversity management (options, alternatives), lifecycle management, context evolution (substitute products) and multi-representation management (different configurations of the same product corresponding to different business views). However, the systems are still very rigid and complex to handle. This is due to the fact that PDM/PLM systems manage information at a representation level which doesn't allow full collaboration. Indeed, managing files and deliverables in a global system makes the exploitation of information very tedious. A second drawback is the lack of information traceability since no relationships are expressed between different domains representations, leaving it as informal knowledge kept by experts where it should be formally expressed and capitalized. The management of multi-representation is done through the configuration concept realized in the form of a tree description.

The tree description of configurations (shown in Fig. 2. as a list of identifiers) requires, for their management, the definition of a configuration reference, and from that point, the identification of the derived configurations.

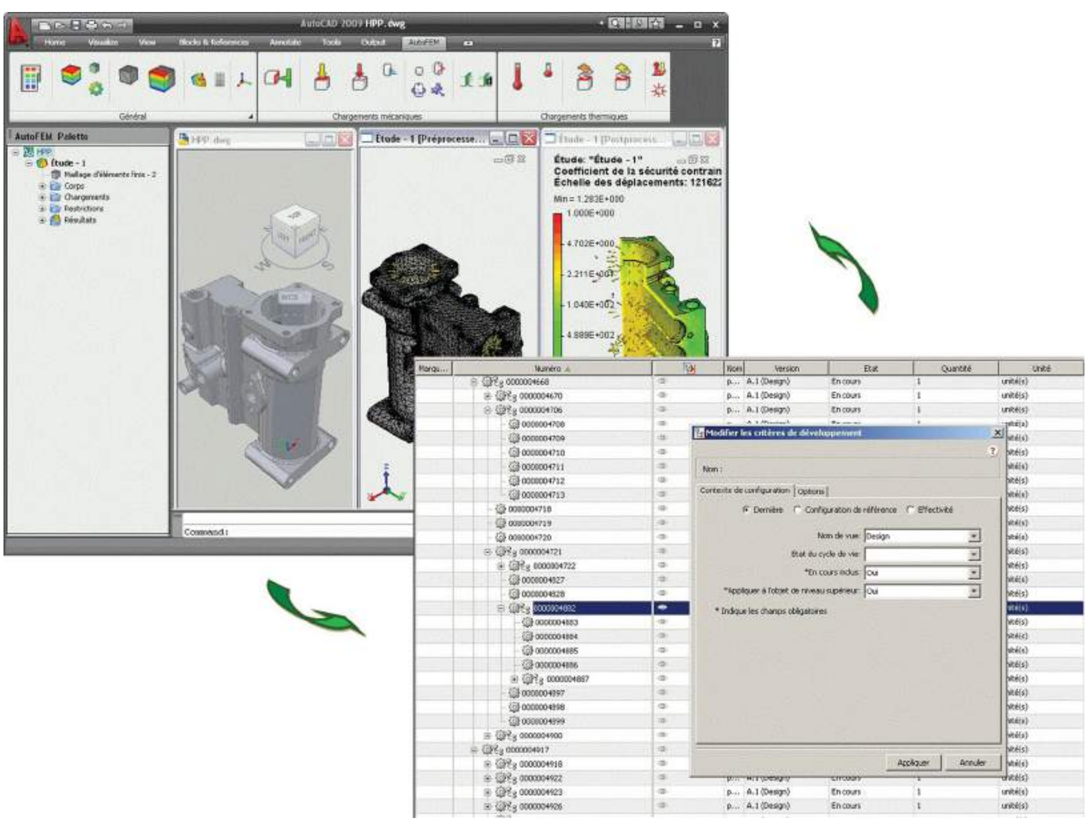

Figure 2. Different points-of-view of the same digital mock-up according to different domains in the product development, extracted from a PLM system. Adapted from [12].

This leads to the identification of the reference configuration data as the basis, common to all other configurations. This work is usually tedious and difficult. It can also be questioned and challenged at any time if a new configuration is to develop, which can change the definition of the reference configuration.

Some research works proposed approaches based on the concept of inheritance to manage multiple knowledge representation. They specify a central model, with high levels of abstraction, allowing interoperability and consistency management into the digital model [8] with associated processes and organizations [21]. However, these models are still based on the description of data trees, limiting the extension to new areas of the representation using abstract classes.

Some other research works on CAD models, allows the translation from one CAD model to another one with different domain knowledge and perspective. They are based on heavy geometrical algorithms leading to long processing time, and the loss of models associativity necessary to changes management [10]. Other research works led to the development of interfaces that allows the annotation of geometrical models in order to generate other models, using databases of specific geometrical functions and some processing in order to position these functions [15]. In all cases, a first geometrical model is used as a reference from which are derived other models specific to a domain knowledge and perspective, with associativity often based on changes propagation from the reference model, which constraints the generation of the derived models.

Thus, it is important to be able to manage multi-representation in a more flexible and progressive way, and at the same time keep the independence of domain experts in constructing their own representation, and save the association and dependencies between models for changes management.

Managing points of view in the context of use of the digital mock-up is thus, still an important industrial and scientific challenge in order to get more flexibility and scalability. The concept of product model is often used to describe and organize the huge variety of product knowledge.

2.2. Product meta-models

PLM systems are based principally on conceptual models representing different types of product information. These models gather product-related knowledge by identifying the different concepts (which we refer to as information) and the relevant relationships between them.

Product modeling throughout the whole lifecycle results, after implementation, in the spine of the PDM information system. Often product model representation in PDM systems is reduced to the description of its structural trees (or Bill of Material – BoM) and related geometry. In reality, the relevant product information is not limited to an organic or physical description (geometry, structure). Other elements of information could be taken into consideration such as:

- Functional description (functions that have to be fulfilled by the product)
- Behavioural description (how the product would work in order to ensure functions realization)

This tripod constitutes the basis of FBS (Function – Behaviour – Structure) modeling approaches often used as a foundation for mechanical data modeling and structuring [4].

During the two last decades, a lot of research works resulted in the elaboration of different product models. One of the first efforts in product modeling lead to the FBS [9] conceptual framework which represents the common basis for a large number of product models. As explained before its particularity is that it decomposes the product into 3 different aspects which are: function, behaviour and structure. Other models include specific description of the technical solutions and parameters. In [8] they developed a modeling platform standing on 4 principal models. The model called CPM (Core Product Model) is a generic product model, simple and extensible which represents product information throughout its whole lifecycle. The MOKA model has been developed in the Esprit project [19]. Its goal was to propose methods dedicated to knowledge engineering through a UML based model described by four different product views: structural, representation, functional and behavioural view. The FBS-PPRE model [14] is based on the FBS framework with an extension in order to address different kinds of enterprise objects (products, processes, resources, and external effects).

All of the previously presented models tried to capture the information concepts that forms the product, thus keeping them generic, while at the same time integrating some product design information from a functional and behavioural point-of-view. But in general they lack the different business concepts which are as important in product development as product intrinsic information.

2.3. Business modeling

In an effort to complete the work already done by the product models, some researchers were working on adding business information to product models in order to extend them. The business information describes the main elements that contribute to the transformation of the product (or components) states, such as for example, business processes and business rules. This is what is commonly referred to as business knowledge.

It is very important to consider business knowledge when building a product model, in order to identify the different relationships that it has with product information, thus, allowing the combination of business and product information that increases collaboration, since business operation are going to affect product information through the identified relationships. The main works that we can find in the literature is the extension of a product model by business knowledge in order to enhance collaboration and operate knowledge integration as soon as possible in the design and development process. Business knowledge can be separated into different types regarding the nature of the process, such as manufacturing knowledge, design knowledge, etc. In this paper, knowledge types are not going to be explored since they are out of the scope.

In [22] the authors propose a methodology and a product model in order to manage manufacturability analysis or process selection, and synthesis (constraints integration) simultaneously, to let the product definition progressively emerge. This work is an effort in the integration of a design for manufacturing (DfM) technique that resulted in the association of product information from a product model with business information (which, in this case is manufacturing).

In [5] the authors proposed the MUVOA model which is a product model that gathers product information and design for assembly business information. This model is decomposed into 2 main parts, the first one is information from product domain which gathers product points of view, and the second one is assembly process domain which regroups assembly process points-of-view. The second part is the business modeling part of the assembly process. The authors integrated this point-of-view early in the design in order to impact the decision making regarding detailed design, thus improving the assemblability of products.

In [13] the authors introduced the concept of interdisciplinary constraints which tries to map the constraints of each business point of view back to the product model as shown in Fig. 3. This concept allows the inter-connection between different business design constraints by mapping them to intrinsic product information in order to enhance information communication flexibility, and the management of conflicts.

Product information associated to business information allows the covering of a specific processing context regarding information but it is not complete. Product models that are proposed lack the system decomposition point of view which is relevant in defining the context in

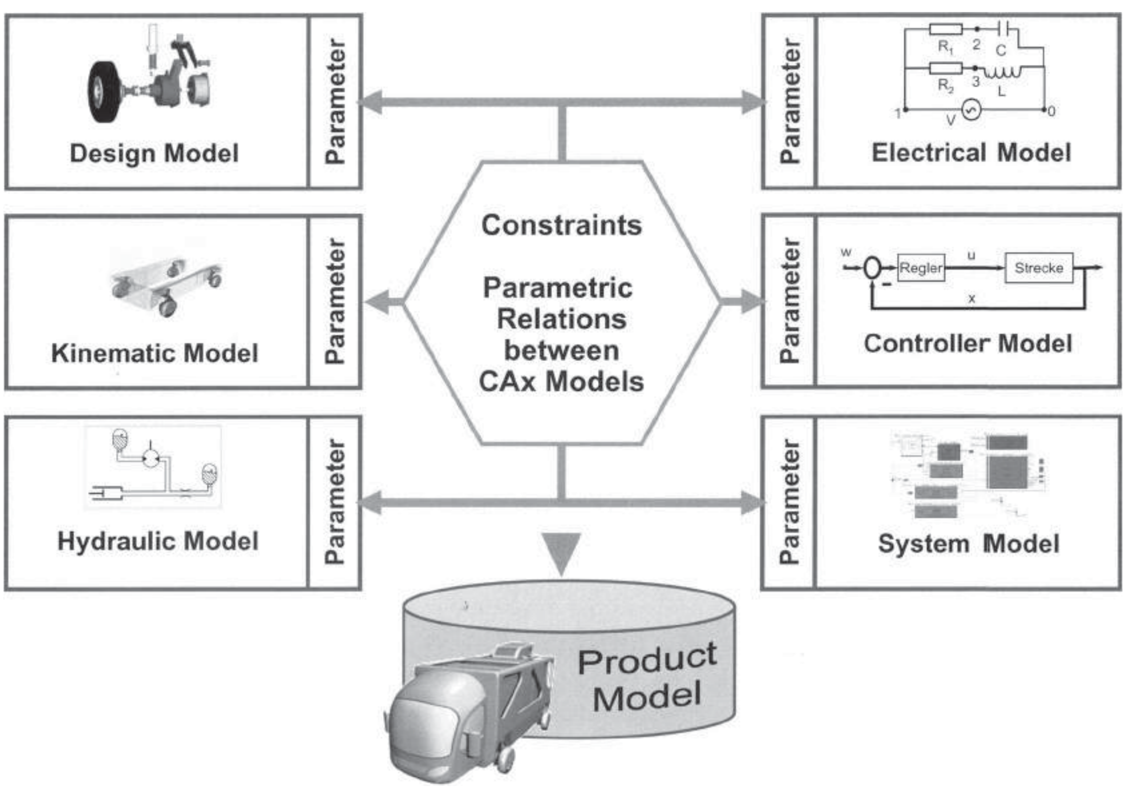

Figure 3. Interdisciplinary constraints concept [13].

which is developed a product. In addition, the intervention of teams in product development is not punctual, but rather in different phases of the product lifecycle. Thus it is important to integrate the temporal aspect in defining the context in which is developed the product. In fact, in order to extend this covering, the integration of other concepts such as systems decomposition from a product point-of-view as well as from an organizational point-of-view, and the temporal context embodied by the product lifecycle (which is going to help managing information across the different phases of the lifecycle of the product) is needed.

2.4. Systems engineering

Systems engineering is a methodological approach that allows the mastering of systems and complex product design [16]. For [11] it allows a balanced design of a solution that satisfies requirements, in addition to the project goals in terms of cost, delays, risks, etc.

The standard EIA632 which is used by aeronautic, manufacturing and military industries, defines a system as a set of required products for the achievement of a goal or a function. A system is composed of required products for the achievement of an operational function called "end product" and products necessary to their realization, commissioning, maintenance and withdrawal, which are called "enabling products" [1]

Decomposing the system into end products and enabling products, results in a multi-level hierarchy. For each level of this hierarchy, regarding the end products, the processes corresponding to each enabling product as represented in Fig. 4. are going to be used in order to specify, model, and develop them further.

Each one of the processes corresponding to the enabling products is going to intervene in the whole product lifecycle, constituting for each end product, at the different levels of the system hierarchy, the processes where the end product is interfaced with its contextual environment (machines or workers in the factory during the manufacturing for example). In other words, managing the system means managing the end products as well as the enabling products from an organizational point-of-view since the end product is confronted to the organization of its project through the enabling products, and from an end product decomposition point-of-view which allows the management of physical interfaces and possible conflicts between sub-systems and components.

2.5. Product lifecycle

Product lifecycle is a concept that regroups the different phases which the product passes by during its life [23]. One of the definitions of product lifecycle regroups three main phases which are: beginning-of-life, middle-of-life, and end-of-life.

The product goes through different processes that are distributed among the different phases of its lifecycle. If one knows the temporal context of a business process means that one knows which information is relevant or not. In this vision, the use of the product lifecycle definition in order to manage information of different business processes is relevant, since it allows the sorting of information according to the product lifecycle phase.

3. Facet management framework

The facet management framework presented here is a first conceptual answer the authors are proposing in order to enhance information collaboration by managing different points of view. The main idea from which emerged this proposition is the possible evolution of product information representation. In the state of the art, on one hand, CAD systems emphasize the geometrical and topological representations of the product along

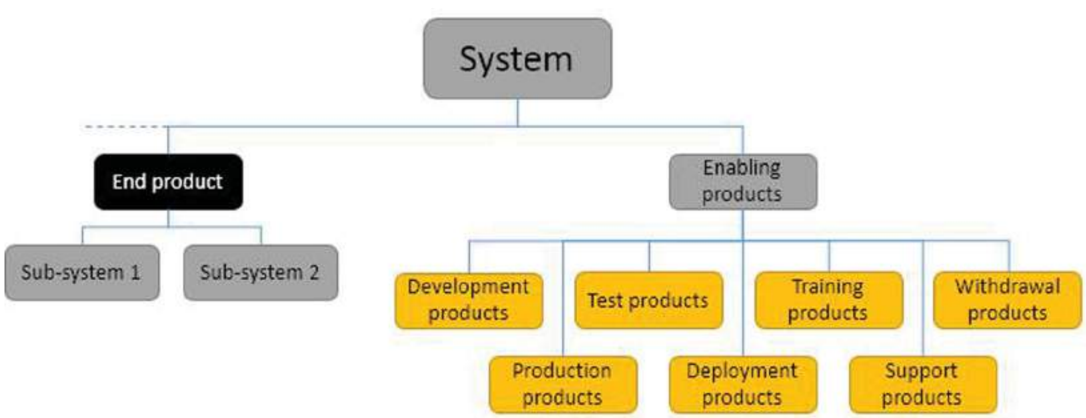

Figure 4. Whole system decomposition in the context of the EIA-632 standard [16].

with some other information such as components' materials. This vision restricts the representation of the whole product information into a low level, structural representation. On the other hand, PDM/PLM systems propose a global product information management framework, based on the management of different enterprise information artefacts (files and deliverables) which, however, doesn't enhance collaboration since it doesn't trace information along product lifecycle.

Starting from this observation, one can think of a solution which gathers the advantages of both solutions, by integrating many representations of the product in its description. The ultimate goal is then, to enhance CAD systems by making them capable of modeling different types of information related to different representations, and by building them based on interrelated data models capable of tracing information. This enhancement requires to build product data models and business data models by coupling them dynamically in order to avoid a complexity explosion while managing the system, thus, leading to a "heterogeneous knowledge integrated CAD model".

The approach proposed here is focused on the elaboration of a solution that allows the dynamic coupling of data models. The building of data models is not discussed here since it is not the purpose of this approach. The approach needs already existing data models, and represents a higher abstraction layer which manages lower level information from these models.

3.1. Facet management framework

The main challenge of the facets Management Framework is to ease information sharing between the different actors of the project, the propagation of information in the different phases of product lifecycle, especially the product development phase and the flexibility it can generate. Indeed, interoperability between information systems by integrating interrelated models facilitates the sharing of information, in addition, the use of the concept of facets allows to rationalize information and present it in an understandable form depending on the context, at the right time.

These interdependent models would allow: (1) the reuse of information, know-how, and knowledge, (2) the sharing of information between different actors that promotes the removal of artificial barriers between activities in each area, (3) the coordination of tasks and processes within the same project, (4) a conflict management from both technical product perspective and, organizational project related perspective, as well as (5) a good traceability of information that can be used to get back to the decisions of such development.

3.1.1. Definition of a facet

The facet is a set of information involving four main perspectives as shown in Fig. 5., which are: product perspective that is represented by a product model, business perspective represented by a business process modeling, system decomposition perspective on both technical and organizational aspects, and a chronological perspective represented by the product life cycle to set the context in which is placed the relevant information.

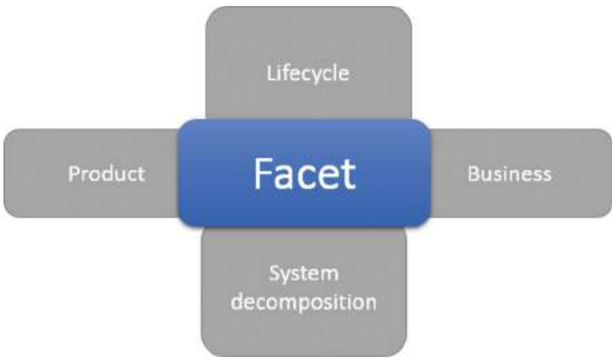

Figure 5. The definition of facet gathering the different points-of-view.

The purpose of using the facet concept is to gather all the information needed by an engineer in a given context related to product information (such as product geometry or topology), associated: to business information related to the product development process (such as manufacturing or structural analysis), to product decomposition into subsystems and components by identifying the various interfaces among them, and to a temporal scale represented by the product lifecycle which allows the establishment of the traceability of information.

3.1.2. The establishment of the facet concept and its use

Starting from a main core product information, we gather the various business models around that same reference (Fig. 6.). The main core will consist of product intrinsic information, that will have a direct impact on product structure, allowing the detection of possible conflicts from different design or development constraints.

To ensure the propagation and sharing of information between different teams during the development, the various business models are connected to the main core. This whole set of information can be seen in two different ways: a global model combining all business information and product information which increases the complexity of managing information, and a sum of interconnected models (thus interoperability of models), which reduces the complexity on the information management.

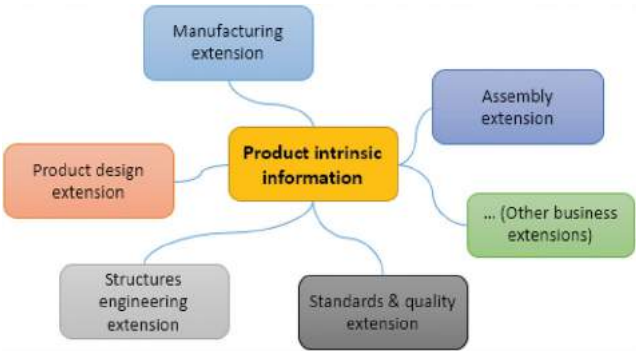

Figure 6. Connecting the product perspective with the business perspective.

In the establishment of the facets, the second context is considered, in which we choose to see a sum of interconnected models, allowing us to set up a specific extension in order to manage facets, which in turn will manage product and business information. The decomposition of the system from a technical point of view (end product) and organizational (Enabling product), plus a time scale represented by the product life cycle to ensure the traceability of information are integrated.

In the Tab. 1. one can see some examples of different facets that include information defining the application context of each facet.

Table 1. Facet concept as a combination of different points of view.

Facets	Product perspective	Business perspective	System perspective	Lifecycle perspective
Fc1	Product Structure	Structural engineering Mass optimization	Gearbox casing	Design
Fc2	Geometry	Thermoplastic molding	Inlet manifold	Manufacturing
Fc3	Topology	Engine architectural design	Engine	Design
...	...	...	...	...

3.2. Facet manager model

Using this definition of facets, a model that manages the points of view is developed based on the reference information set which gathers intrinsic product information. This model is shown in Fig. 7.

Starting from a product perspective embodied by the ProductInformation class, extensions are added regarding each domain knowledge used in the product development process, and regrouped as BusinessInformation class. The two previous classes inherit from InformationEntity class which is an abstract class that represents information broken down into small pieces easily managed and represented using a specific representation mode selected from virtual, linguistic, algorithmic, symbolic or pictorial [2]. The SystemDecomposition class which is also abstract embodies information about the whole system in product development. It is inherited by

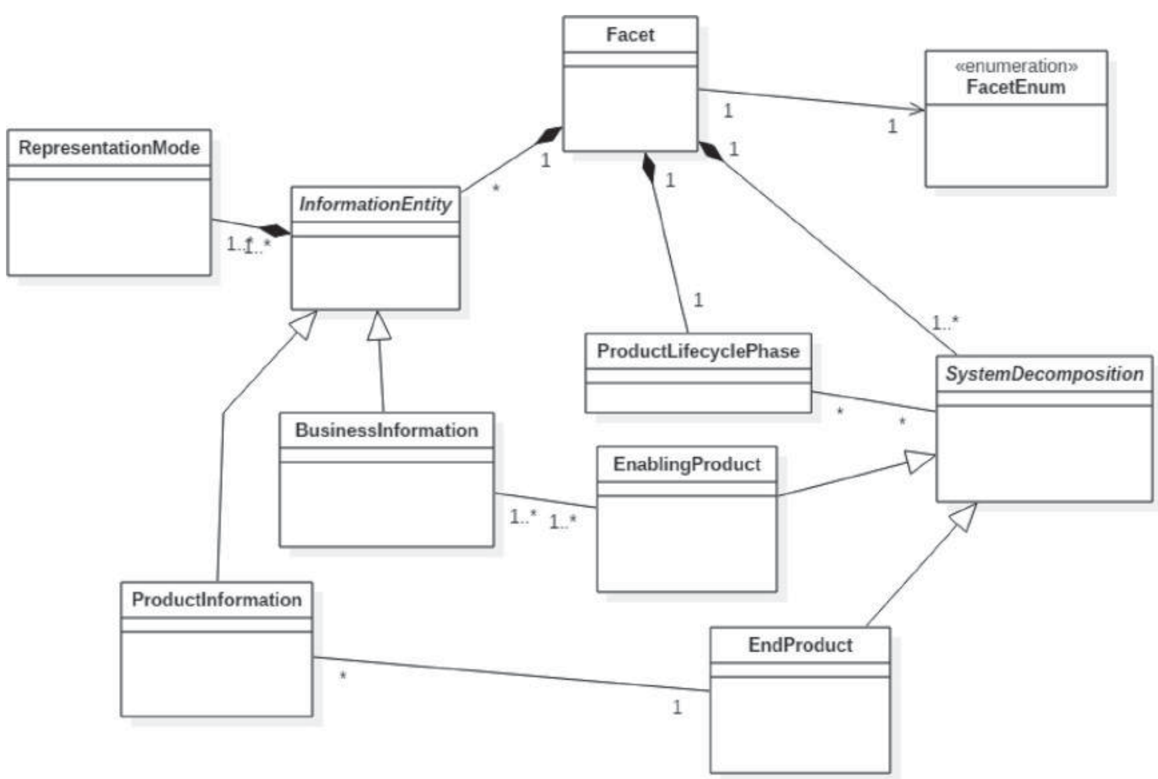

Figure 7. Points-of-view manager basic model – Extension connected to the product model to manage the different points of view.

EndProduct class which gathers end products information, and by EnablingProduct class which gathers the different enabling products. ProductLifecyclePhase class gathers information about the different phases through which the product passes. It is related to the SystemDecomposition class since the enabling products need a temporal context to be used. The enumeration class FacetEnum is here to gather the points of view that could be defined by the expert in the PLM system.

This model represents an additional layer, a higher level of abstraction which manages lower level of abstraction information. In fact, product information, business information, system decomposition and product lifecycle represent the lowest level of abstraction, since they represent the basis on which would be constructed an information system that does the management work. Here the model uses the lower level models by coupling various information elements from them (information entities within the models) in order to construct a facet relevant to one context, and present it to the user.

Using this points-of-view manager allows the flexibility that we are searching for when moving from one process specific information representation to another, while maintaining associations between them.

4. Case study

This case study is used as a demonstrating context of the relevance of the proposed framework, and focuses upon the use of CAD models by business experts, and the implemented processes in order to get multi-representations of this CAD model.

This took place within a large automotive design and manufacturing company, and focused upon the organizational approach taken within a developmental enterprise-wide environment which would support a large scale design project. The context of this study was in the company's mechanical engineering department which was responsible of the development of different mechanical engines and powertrain organs, and took part in motor engines development projects. The authors had the opportunity to exchange with multiple domain experts and get an insight on the different techniques, methods and tools used during the product development.

One of the principal facts that the authors noticed is the use of a homemade PLM system in order to manage data between different business experts. However, the use of such a system was limited to the exchange of references regarding CAD models built under a legacy tool. The PLM system gathered different engine development projects sorted by their configurations. For each project there were different configurations of the same engine representing different automotive applications, and each one of these configurations had a reference CAD model, developed or under development, that was identified by a special and unique ID.

The first problem identified was the recovery of relevant CAD models. Engineers had to ask the team responsible for managing the CAD model of the project, the relevant ID in order to recover it. There were configuration management tools used, but they weren't accessible for all engineers, even in a read-only mode, thus, it was very difficult to get the right information regarding the right configuration or right version of the CAD model, and a further work of actual configuration was needed, and that affected considerably the working time of engineers.

The second problem is the relevance of the CAD model to the business process. After getting the right CAD model, each business expert had to transform it in order to fit his working point of view. For engine architecture engineers, there was no need to transform the representation given by the CAD model, but needed lightweight representations since they worked on whole engine architecture,

Safety engineers, needed the architecture of the whole engine as well as multidisciplinary information in order to assess different security risks related to the architecture of the engine (components placement in the engine) such as flammable products leakage, electrical risks, and the impact of thermal energy generated by some components such as the turbocharger. Thus the need to complete the lightweight CAD model with multidisciplinary information gathered by the security engineers, after meetings and interviews with the related experts. With the implementation of the facet manager, this whole information gathering process wouldn't be needed. A facet specific to safety engineers would have been built, that extracts information from the relevant models by getting a lightweight geometrical representation, completed with the needed multidisciplinary information, thus, improving the working time of the team.

One can see that the central object used is the CAD model extracted from the PLM system, and then modified in order to fit each one of the relevant points-of-view. This is due to the fact that there wasn't yet an effort to model each business domain regarding experts' knowledge and at the same time, the lack of interoperability between the different systems in the company and the dissociation of the different data models regarding the product.

It is in this kind of situations where it is beneficial to implement the facet framework. In fact, enabling each team to access the right information easily, and facilitating the collaboration by a direct communication through appropriate channels would improve the project management in terms of cost, time, and performance. Each

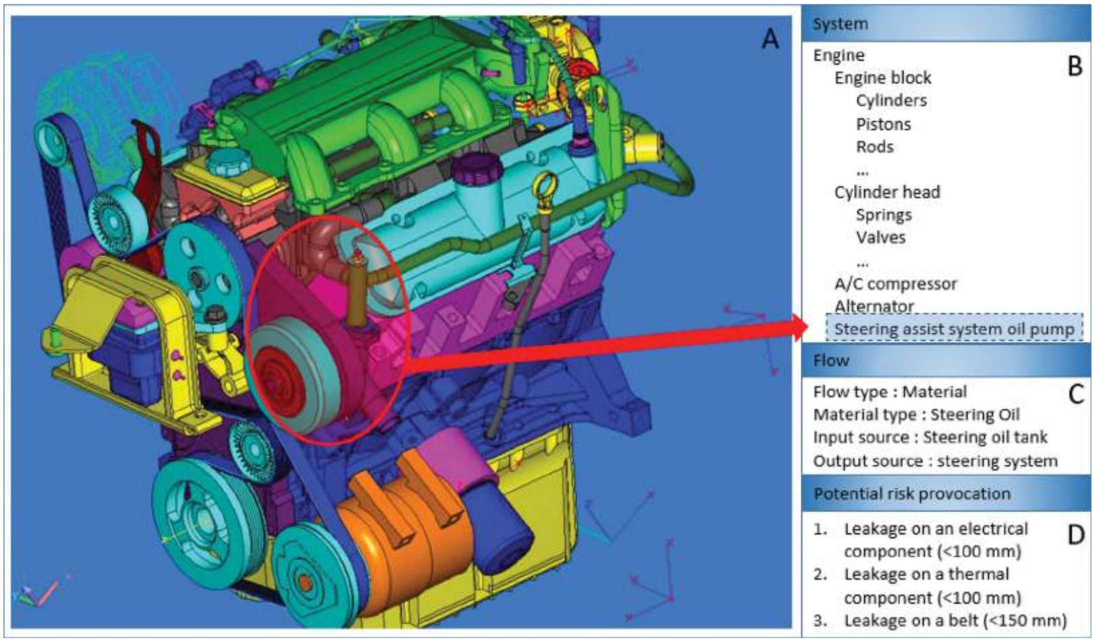

Figure 8. Example of a facet representation for safety engineers, adapted from [27].

development team would use a relevant facet in order to have the proper information representation they need. Then, safety engineers would have a facet composed of a lightweight CAD model representation gathering geometric information along with functional and technological information for each sub-system or component.

As an example, a gasoline engine decomposed into several sub-systems, and components. From the safety engineers' point of view, a facet has to be built that gathers geometric information about the product, represented in a classical CAD model representation (Fig. 8(a)), along with the system decomposition (8(b)), the flow information of the subject sub-system (Fig. 8(c)) and the potential risk related to the sub-system (Fig. 8(d))

In Fig. 9 the objects diagram translates Fig. 8 in terms of object instantiation of the facet manager model.

The object diagram shown previously gathers information at an abstract level because the different models regarding each perspective weren't taken into consideration since they are out of the scope of this paper. One has to see the objects of this diagram as connected to specific models each one gathering information in its perspective

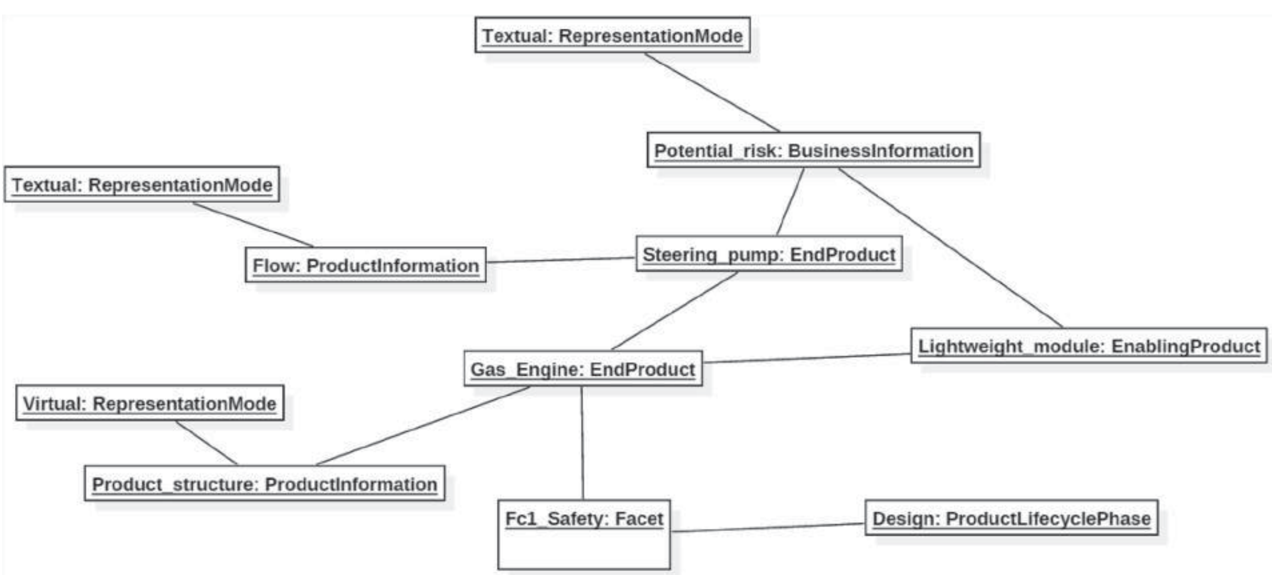

Figure 9. Instance of the facet manager model related to safety engineers' facet (Fig. 8.).

(i.e. product_structure would regroup all the Gas_Engine detailed physical structure).

5. Discussion

The elaboration of the facet framework needs to deal with the elaboration of the different low level models regarding the four perspectives that we are considering in order to manage multi-representation (product knowledge, business knowledge, system decomposition, and product lifecycle). The main challenge is then the elaboration of these models, especially regarding business knowledge, which can be tedious, since the vision of business information can change considerably from one company to another. Another challenge would be the construction of the different facets, which has to be done jointly with business experts since they are more aware of the relevant information to represent when working on a task or completing a process.

6. Conclusion

This research work presents a framework in representing and managing information in the product lifecycle, especially its development process. The framework is based on the concept of facet which takes into consideration different information sources that are product information, through a product model gathering intrinsic product information and business information from experts' knowledge in order to ensure the reuse of existing knowledge and improve the collaboration between engineers, systems decomposition related to the structure of the product from a technical and organizational point of view in order to enable conflicts management, and a temporal scale represented by the product lifecycle which allows the traceability of information among different information versions and product configurations. This framework is then used as a basis to construct a points-of-view manager model in order to include the different points-of-view from a data modeling perspective. Further work concerns the possible integration of the concept of abstraction levels in order to manage the different levels of abstraction in each point-of-view previously presented.

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