Integrated Management of Automotive Product Heterogeneous Data: Application Case Study

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Abstract. The product development process (PDP) in innovative companies is becoming more and more complex, encompassing many diverse activities, and involving a big number of actors, spread across different professions, teams and organizations. One of the major problems is that development activities usually depend on many different inputs and influencing factors, and that the information that is needed in order to make the best possible decisions is either not documented or embodied in data that is spread over many different IT-systems. In this context a suitable knowledge management approach is required that must ensure the integration and availability of required information along with the federation and interoperability of the different Enterprise tools.

This paper presents a description of an industrial use case application where the innovative methodology researched in the iProd project is adopted. This methodology aims at improving the efficiency and quality of the Product Development Process (PDP) by means of a software ontological framework. The methodology is first briefly outlined and then its application is illustrated with an automotive application case developed together with Pininfarina. This case demonstrates how it is possible to capture and reuse the knowledge and design rationale of the PDP.

Keywords: Enterprise integration, Enterprise interoperability, PDP, ontologies.

1 Introduction

A reduction of the development time for new products and an improvement in productivity and quality together with a reduction of costs are key objectives for company competitiveness. These objectives are achieved through three fundamental elements: corporate strategy, processes optimization and computer support technologies.

The nature of the Product Development Process (PDP) within modern organizations has altered dramatically over the past decade as the products themselves became more complex. The engineering of such complex products as automobiles, airplanes and appliances of any type is highly knowledge-intensive. Vast amounts of very

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different kinds of information and knowledge have to be managed in a precise way. The product and process complexity in these industries is steadily increasing. The life cycles tend to get shorter, and the time and cost pressure are increasing. The Product Development Process (PDP) is therefore becoming more and more distributed and networked – not just within an enterprise but even between professions and teams along supply and design chains in a globalized economy [3].

In this context data and knowledge management technologies are of fundamental importance for industrial innovation, provided they are integrated in the enterprise processes, in the organizational structure, and can be flexibly adapted to company evolution. Present ICT solutions address parts of product development separately, but an integrated approach that includes data and services required for the whole PDP does not yet exist.

This paper presents a real case study in the field of automotive where the innovative solution researched in the iProd project [1] is adopted. iProd aims at improving efficiency and quality of the PDP of innovative products in the aerospace, automotive and home appliances industries by developing a flexible and service oriented ontology-based software framework. This framework, reasoning and operating on a well-structured knowledge, will be the backbone of the computer systems associated with current and new product development processes.

2 iProd Methodology

The iProd project has the objective to develop a software platform which addresses the high amount of heterogeneous information involved in all activities associated with current and new product development processes, from the definition of subjective goals from customer viewpoint (and subsequent description in the form of technical goals), to the drawing of a Test Plan (physical and virtual) and its monitoring, to final approval and product validation. This Process involves most company departments, such as Marketing, Quality, Experimentation & Design, Experimental Constructions, Technologies and Suppliers. Control of such a wide-ranging process, however, necessarily requires the introduction of computing tools able to acquire, analyze and structure large, rapidly evolving and often conflicting amount of information, with the objective to rapidly adapt the flow of knowledge to the operational flow of the activities, keeping employees and stakeholders up-to-date with the progress of the work, helping in performing complex tasks and taking decisions. More in detail, iProd addresses the activities related to requirement definition(part in product conception and part in user needs), requirements specification, test planning and optimization, system integration testing and acceptance testing (product delivery).

According to the main concepts of systems engineering and to ISO15288 standard (which establishes a common framework for describing the life cycle of "systems created by human") the main sub-processes managed by the iProd framework are:

- System requirements (customer view)
- Requirement Analysis (technical view)
- Verification Plan Management
- Virtual & Physical verification execution
- System Validation

More details on the methodology implemented in iProd can be found at [2]. To achieve these goals, iProd applies knowledge management (KM), reasoning engine (RE) and process integration and automation technologies.

The heart of the iProd framework is in its ontological foundations: in contrast to typical database driven software tools, iProd is based on a set of ontologies that map design engineering domains like product structure, requirements, processes, design rationales, optimization and creates links between them. The resulting consistent, domain independent, set of ontologies is complemented by a set of domain specific ontologies that capture the specific characteristics of the domains of application (like automotive or aerospace). This ontological framework and its design approaches are not in the scope of this paper, but more details can be found in [7, 8]. Their main goal is to capture the knowledge related to the PDP and reuse it as much as possible.

3 Application to the Automotive Context: Pininfarina Case Study

Being iProd focused on capturing, reusing and operationalizing the knowledge related to the product development process, the application context selected for the present paper puts its attention first to the PDP of one of the major European industrial markets: automotive. iProd can be generally applied to all type of markets that can formalize their PDP, including (but not limited to) aerospace, home appliances, electronics, embedded systems and services.

The PDP in automotive industry is affected by a close collaboration of OEM(s), tier 1 to n-suppliers, and engineering service providers with many interfaces within the development networks, not only between the different companies but also between the diverse stakeholders within the different PDP steps, from product design via prototyping, testing, production ramp-up to production. The main PDP steps are separated by special milestones, so-called Stage Gates [4] or Quality Gates (with a stronger risk management approach) [5]. The same milestones must be passed in each development project, requiring a set of criteria that must all be fulfilled for successfully passing to the next step. The automotive PDP is strongly focused on specifications that are based on functional requirements that can be experienced by customers. The required criteria at each gate are thus often derived from these functional requirements. The automotive PDP has strong emphasis on keeping the functional requirements consistent and valid for testing, particularly when they are transferred to technical specifications for components and modules.

During the development of a car, huge amounts of data are handled. The recent Mercedes-Benz C-class has more than 2 Terabytes of product data [6]. The complexity of the PDP is largely reflected by the amount and distribution of different IT systems used all across the development network, but these tools are frequently not fitting together, using different data sources and file formats, resulting in fragmented process chains with island-like software systems and discontinuous information flows. In summary, the main deficiencies that can be identified in the automotive PDP are:

- Communications among the supply chain (OEM, TIER 1, 2 and 3)
- Complexity of the design and development methodologies
- The use of experimentation in the PDP

In this context iProd provides a solution that allows an integrated management of this heterogeneous data (as explained in section 2). This approach has been applied to the PDP of the italian leading design and engineering company Pininfarina.

The use case presented in this paper is focused on the design and optimization of a car door structure. For the sake of simplicity (and data confidentiality), this use case is not covering the entire PDP, but only part of it and only the higher level details. Doors are complex structures that contain just about everything that a car as a whole contains except for power train elements. Customers directly interact with car doors and they are aware of their characteristics called “dimensions” by Pininfarina, or called “attributes” by Ford.

The door that has been taken into consideration as a use case for the iProd project refers to the NIDO concept car (Fig. 1) which was first presented to the public in September 2004 at the Paris Motor-show.

Fig. 1. Pininfarina "NIDO" (Paris 2004)

The core business process that Pininfarina uses to develop and take products to market is called “Shape”. This process is used from styling through design development and production projects (in Pininfarina or at the OEM) and combinations of these areas. All Pininfarina projects use the same “stage-gate” approach: it is so simpler for a Core team to understand what to focus on as a project progresses. Also, “stage-gate” makes it possible to standardized and simplify the project review process though the use of gate reviews at which all areas of the project can be assessed. The process of Shape is showed in Fig. 2 and it is divided into six phases, each phase is called Stage that is divided into different sub-activities.

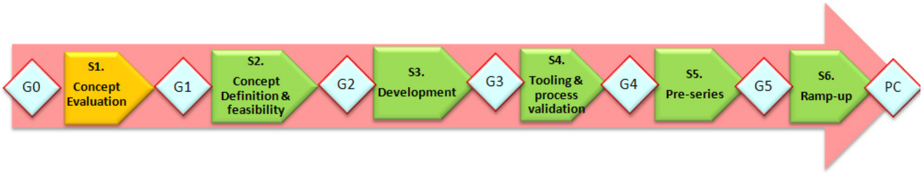

Fig. 2. Pininfarina "Shape" PDP diagram

iProd covers essentially the phases S1-S4 and is able to capture all the knowledge related to product structure, requirements, competitors management, tests planning and verification as shown in Fig. 3. However, for the present case, focus will be put only on steps S3 and S4 for the sake of simplicity. In order to apply the iProd methodology, a number of steps are needed to capture process and product knowledge associated with the car door. These steps require the acquisition of the following knowledge As such, a number of items need to be considered:

- The performance tree, which represents a hierarchical decomposition of the requirements for the new product. The first three levels of the tree define the performance requirements that have been further detailed in technical specifications
- The list of requirements, which is derived from market analysis, voice of customer, customer needs, state and safety regulations and deficiencies in earlier series of the product.
- A subjective target value, which ranges between 1 and 10 and is adopted to measure the performance requirements and also for making an analysis of the competitors.
- Technical specifications, which are engineering parameters that have to be specified in order to satisfy a particular performance. For each technical specification one or more tests can be associated that enable to verify the achievement of the specified target.

For all of them, specific ontologies have been developed and illustrated in [7]. As shown in Fig. 3, the correlation between the requirements and the different subsystems impacted is captured by creating nodes in a correlation matrix. Each node can be associated with a set of tests called Performance Drivers and related target engineering values that if satisfied allow to deliberate the subsystems of the product. Once the list of requirements and tests is completed iProd provide an initial work breakdown that can be further elaborated by the users to create a first plan of the task assigning timing schedule and responsibilities to the activities involved in the product development process.

An optimized task planning is then computed and suggested in real time by iProd to the designer to support them in making the best decisions possible on the base of the current situation of the on-going activities. Strategic key performance indicators are indeed available to monitor the evolution of the plan. This platform enables the engineers to address also the critical phases of the PDP when redesign loop are necessary due to test failures or significant delays in the execution of the tasks.

Performance Tree	Target Setting					[C.M.] Correlation Matrix							
	Subjective T.S			Objective T.S.		Product subsystems							
	Competitor_1	Competitor_2	New project	PTS Target	Test code	[SS] - FRONT LEFT DOOR INNER PANE	[SS] - FRONT LEFT DOOR EXT. SKIN	[SS] - ACOUSTIC PANEL	[S] - DOOR HINGE	[S] - BOLT M8X30	[SS] - INTERIOR DOOR HANDLE	[SS] - EXTERIOR DOOR HANDLE	[S] - DOOR CATCHER
[TLR1] - ERGONOMICS													
[TLR2] - EXTERIOR ERGONOMICS													
[TLR3] - FRONT DOOR - OPENING/CLOSING	7	8	9										
[PTS] - opening load				35N	7N8087				X			X	X
[PTS] - handle dimensions				200 x 30 x 25 mm	2P1							X	
[PTS] - handle distance from the ground				10Nm	3P1							X	
[PTS] - available hand space				...	4P1							X	
[PTS] - Interior Sag test				...	5	X							
[PTS] - feed-back of the opening pressure				300N	7N8087				X			X	X
[PTS] - opening angles in different opening position				...	9D				X				
[PTS] - opening angles in different closing position				...	10D				X				
[TLR3] - FRONT ACCESSIBILITY	6	8	8										
[PTS] -				...									
[PTS] -				...									
[TLR3] - ERGONOMIC/FUNCTIONALITY OF DOOR OPENING DEVICES	8	8	8										
[PTS] -				...									
[PTS] -				...									
[TLR2] - INTERIOR ERGONOMICS													
[TLR3] - FRONT DOOR - OPENING/CLOSING	7	8	9										
[PTS] - Timing for up and down in glass operation													
[PTS] - handle dimensions				...	12D						X		
[PTS] - opening load				...	11D				X		X		
[PTS] - available hand space				...	13D						X		
[PTS] - feed-back of the closing operation				...	14D				X		X		
[TLR1] - VEHICLE BIW													
[TLR2] - FRONT LEFT DOOR BIW													
[TLR3] - FRONT LEFT DOOR BIW - OPENING/CLOSING													
[PTS] - Door YIELDING UNDER LOAD				15 mm	7N9312				X				
[PTS] - Door PERMANENT YIELDING				5 mm	7N9312				X				

Fig. 3. Correlation Matrix between Product structure and Requirements for Pininfarina use case

A typical virtual test performed in car door design and illustrated in this section is represented by the door sag test. This activity is positioned in Stage 3 "Development" of the Pininfarina "SHAPE" PDP when product engineers carry out engineering development activities and CAE experts carry out virtual and physical engineering validation. The objective of the analysis conducted is to predict the vertical sag behavior of the door assembly.

The complete virtual design process is described in Fig. 4 and involves four main simulation tasks: CAD model creation; meshing of the created CAD model; finite element analysis preparation and virtual test execution. These simulation tasks are performed by different tools and are integrated in a seamless way in a simulation workflow that allows automating the execution of this process.

In this specific process different versions of hinges have been designed and need to be tested on the virtual prototype of the door. The virtual test definition and its associated simulation workflow are shown in Fig. 4 and Fig. 5 (implemented by using Noesis Optimus). The simulation workflow is dynamically generated from knowledge base by means of reasoning on its ontologies [9].

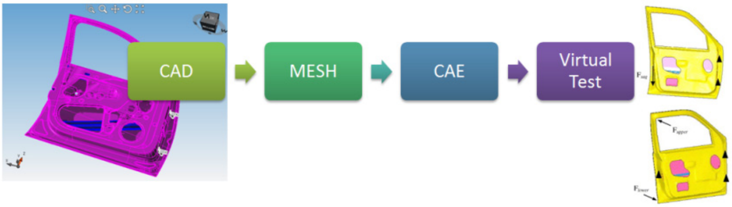

Fig. 4. Virtual design process of a new car door in Pininfarina

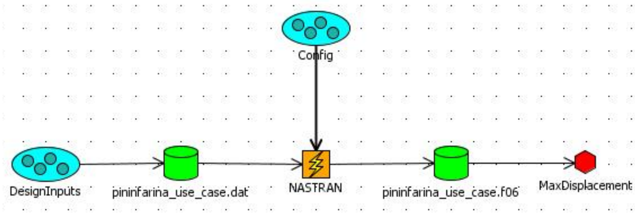

Fig. 5. Simulation workflow that performs the virtual door sag test in Pininfarina case study

The main result achieved by the application of the iProd approach for this use case can be quantified in terms of:

- Reduction of the number of physical tests by accessing, relating and comparing the physical and virtual tests and their historical results by means of the Correlation Matrix and on this basis replacing a physical test by a virtual test if repeated historical comparisons of their results demonstrates their equivalence
- Reduction of test re-planning time and corresponding cost by replacing current internal meetings procedures for test result evaluation and test activities rescheduling by automatic identification of required new tests and real-time rescheduling
- Reduction of time for project set-up, project status review and assessment and project reset-up after test verification failure by re-using knowledge by means of the Correlation Matrix
- Reduction of the time and costs of test result management (knowledge reuse and feedback) by giving feedback to the designer the test results and by reusing test knowledge for subsequent projects

All these results constitute benefits that produce an increase of efficiency and product quality with a reduction of time to market.

4 Conclusion

In this paper an industrial application case from the automotive supplier Pininfarina has been presented, where the innovative methodology proposed in the EC 7th Framework joint research project iProd have been adopted. First an introduction on the product development process is given and then the iProd solution able to address the complexity, semantic diversity and richness of content PDP is described.

A detailed description of the application case related to the development of a new car door was provided. In that a proof-of-concept of the methodology was developed and the potential benefits that iProd may provide in the product development process was shown: drastic reduction of product development costs by means of an optimized testing process with a higher and more intelligent use and integration of virtual testing models; support for knowledge and competencies extraction, structuring, reusing and sharing also with suppliers; improved focus of new product development with a fast and structured management of competitor and market analysis data and possibility to make more reliable decisions by exploiting structured indicators along product development activities.

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