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SIMULATION IN PRODUCT LIFECYCLE:

Towards a better information management FOR DESIGN PROJECTS

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ABSTRACT

The Digital Factory aims to provide simulation tools for the design of a product and its production system in parallel. However, the Digital Factory is underused in the industries because of the lack of organization and methodology supports, of the variety of simulation tools that compose it, and finally of the amount of data and information generated without tools or information management system suitable for this approach. In this work, we focus on this last point and we propose a tool of integration and information management for product / process simulations throughout the product lifecycle. This tool must be capable of integrating different business views (design, manufacturing, simulation), coming from different information systems.

INTRODUCTION

With the increase of worldwide industrial competition, being able to propose new products in a short lead time and low cost is an important concurrence advantage for companies. In order to achieve it, companies must take into account client requirements and the constraints of different phases of product lifecycle. Indeed, Scholberger amounts to 85% the percentage of defects occurring during manufacture and which are related to decisions made during the product design.

In addition, most of product costs are engaged during the design phase *(Coze et al., 2009)*. Thus, companies should concentrate on effective ways to design products faster, minimising not just only cost and problems related to the design project phase, but also considering problems of others phases of product lifecycle.

In this context, the digital prototyping *(based on the concepts of digital models representing the product, its physical behavior, and its manufacturing process)* is a solution to test and validate a product earlier in its lifecycle *(Hoppmann, 2009)*. The simulation, associated to these digital prototyping, becomes an essential tool to avoid unexpected problems occurring during upstream phases of the product lifecycle, and so it allows reduce time spent in the product design project.

However, if product simulation or its physical behavior simulation can be considered well integrated to the product design project, the simulation of the manufacturing process *(Digital Factory – DF)* is not as much as deployed in companies. Indeed, the DF tools are until now under deployed in the industrial world because of the lack of organization and methodology support, the diversity of simulation tools, and finally the amount of data and information generated with no tools or management information system adapted to this approach. In this work, we focus on this last point and we propose an integration and information management tool to product/process simulation throughout the product lifecycle.

This tool should be able to integrate different views of actors, who interact with themselves *(design, manufacturing, simulation)*. These views are composed by information provided by different information systems support of each product lifecycle phase. This tool, called SIM info, is based on a data model, which takes into account a product view, a production process view and a simulation view, which are interconnected *(Ayadi et al. 2011)*.

The paper is structured as follow: section 2 provides a non-exhaustive state of the art of Digital Factory and its simulation tools. Section 3 presents briefly the conceptual model of information simulation management which the authors based on. Section 4 presents the proposed information management tool. Finally, Section 5 presents the conclusions and perspectives.

1. Digital factory and its simulation tools

With the objective to integrate especially the production phase in the design project, the Digital Factory is defined as the set of software tools and methodologies allowing the design, the simulation, and the optimization of production systems *(Bracht and Masurat, 2005; Kuehn, 2006; Chryssolouris et al., 2009)*. This approach, , originating from concurrent engineering and from Computer Integrated Manufacturing *(CIM)*, aims to reduce validation loops by ensuring, as early as possible in the product lifecycle, integration of the product manufacturability and productibility with business constraints. It can be seen as an excellent tool for decision support interacting with design, simulation and production actors and it can be used since the early stages of the design project. The DF allows the identification of problems related to the production process, and then the change definition of the product or of the production process for more efficient production. It implies the use of simulation throughout a large part of the product lifecycle, from the new product development, through planning equipment manufacturing to the organization of mass production *(Arndt, 2006; VDI 4499, 2006)*. With the methods and tools of DF, manufacturers seek the optimization of production process and the reduction of the production system costs. Thus, companies change their production processes through the integration of simulation in the design methodology and in validation phase of the design.

Despite the existence of many simulation tools integrating Digital Factory, their implementation in companies is until now not enough and does not fully satisfy the needs of the industrials *(Nagalingam et Lin, 2008)*. Several issues explain the roots of this situation:

- Digital Factory is intrinsically complex, due to the different levels of detail co-existing (from the operation on a specific station to the global supply chain (*Wiendahl et al., 2007 ; Boime, 2005*)) and to the variety of simulation type (prescriptive vs. based on events (*Cheutet et al., 2010*)).
- Different actors in the company, with very different point of view are interacting in the Digital Factory scope: designer, agent of simulation production and manufacturer. The variety of views implies a complexity of communication and collaboration that interferes with the objective of best performance in terms of time, quality and cost.
- Even if, according to the Moore's law, the computational power is currently growing roughly at an exponential rate, the simulation complexity is approximately growing with the same rate (*Häegele et al., 2010*). Moreover, the amount of simulation data is growing at the same rate, requiring new techniques of management.

As a consequence, the Digital Factory is becoming more and more complex and today's managers of many businesses are confused with varying technologies and new terminologies that prevail in the public domain.

This led us to analyze the DF on a simulation tool point of view. The first step in the implementation of Digital Factory is factory plant layout, and its purpose is the optimization of the production process. It involves the sensible integration of several essential domains, ranging from the resource database to factory design and layout, factory flow optimization, plant, line and process simulation, part manufacturing, robotic work cell simulation and human resource simulation. This purpose is achieved by a series of tools, such as 3D modelling programs or simulation programs. Nevertheless, the tools of Digital Factory are based on a **PPR** *(Product, Processes, and Resources)* philosophy. Process is represented by a suite of operations, in which are specified the resources *(tools, robot, machine tool etc.)*.

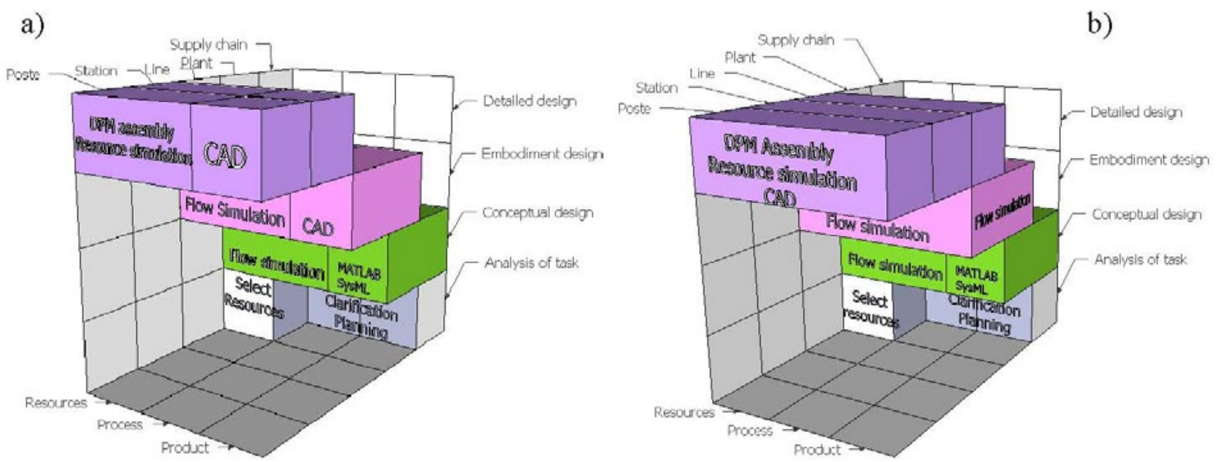

FIGURE 1. *Actual and proposed cartography of simulation tools in DF (Ayadi et al., 2011) .*

Ayadi et al. *(2011)* propose two cartographies of Digital Factory simulation tools *(***Fig. 1***)*, considering three main aspects of simulation:

- The integration of data of product, process and resource,
- The integration of design phases,
- The ability to vary the level of detail of simulation.

The first cartography *(***Figure 1***a)* analyses the existing tools, and the second one presents our proposed cartography *(***Figure 1***b)*.

According to authors, the current cartography demonstrates the lack of interactions between the different simulation tools. For instance, at each phase and each detail, there is a clear separation between the tools acting on the product and the ones acting on process and resources. This separation is reflected in the figure by the vertical line separating the product of processes and resources during the detailed design phase. This creates a gap in the PPR integration: with the current tools, every time a designer makes a change on the product, there is no effect on the simulation of production process and all the process of production simulation must be repeated.

Moreover, there is a clear breakdown between tools acting during the embodiment phase at the line level and the ones acting during the detailed design at the station level. This breakdown implies a large information gap that will be complex to fill in order to ensure the continuity of information flow over all the PDP.

The objective of the proposed cartography is clearly to solve these issues. Most existing simulation tools mainly deal with the detailed design phase. Having more simulation tools during the early stages of product design, i.e. conceptual and embodiment design and task clarification, reduces product time to market and helps to get the right decision as soon as possible. But this implies to integrate new information earlier in the PDP, information that is not common to find at that moment. One can cite as an example for this added information needed by the simulations: production strategy, current production resources and capacities, etc. The addition of this type of information will reduces development and ramp-up time, accelerate product delivery, improve planning reliability and offer considerable savings product costs and time, by enabling design teams to seamlessly collaborate with manufacturing teams.

In summary, in Digital Factory scope, many software solutions based on CAX are already available for product related to their environment, but dedicated for the most part to detailed design phase. Nevertheless, the main issue is not the existence of adequate tools but their capability to communicate between them and ensure a global consistency of the product and its production system.

Very few works propose a solution to enhance the communication between simulation tools. Most of them are dedicated to Computer Aided Engineering, i.e. product simulation behaviour, like *(Joshi, 2004 ; Simulia, 2007 ; Song et al., 2009)*. From our knowledge, only the approach of *(Fortin et Huet, 2007)* has been proposed within the Digital Factory, but they do not tackle the problem of multiple actors in Digital Factory.

As a consequence, the objective of this work is to propose an information system dedicated to information management for simulation in Digital Factory. It is based on a conceptual data model for managing information in the digital factory simulation *(Ayadi et al., 2011)*.

2. Conceptual model for managing information in DF

This section briefly presents the conceptual data model proposed by Ayadi et al. *(2011)*, on which we base for proposing management tool information. The authors propose an extension of product and manufacturing data models, proposed respectively by Gunendran and Young *(2006)* and Molina and Bell *(1999)*, and a simulation data model.

In the product data model *(***Figure 2***)*, "**Product**" class is linked, through an aggregation relationship, to five classes. Ayadi et al. *(2011)* were particularly interested in the subclass "View", which allows defining different views during the PDP. From this subclass, the authors defined the class "**Product Simulation View**", which represents the product and manufacturing information needed to make a simulation. This information is taken from the product model information such as the chosen process, the general shape of product, orders of assembly, the selection of resource etc.

The "**Product Simulation View**" class can be further developed to capture low-level information. In Fig. 7, we so define the "**Product simulation**" class and the "**P-Manufacturing simulation view**" one. The first class is proposed to capture more information in order to facilitate decision making during the product development process i.e. order of assembly, function simulation etc. The second class will serve such a link class of information between the product and their production process.

On the other hand, the manufacturing data model is defined as "an information model that identifies, represents and captures the data, information and knowledge describing the manufacturing resources, processes and strategies of a particular enterprise" *(Molina et Bell, 1999)*. This model captures information relating to four major aspects of the enterprise, i.e. the processes, resources, strategies and views. In particular, the "**Views**" class is related to the "**Facility**" class with aggregation relationship to propose different views of the facility according to the level of detail and the different alternatives proposed.

Ayadi et al. *(2011)* have extended the "View" class with the notion of **M-Manufacturing simulation view** *(***Figure 2***)* that captures all the manufacturing information needed for simulation. An example of information captured from manufacturing simulation view in manufacturing model is plan layout, organization of workshops, arrangement of machines etc.

However, for an integrated approach of product development, these two types of information can work together in the same environment in order to help to make the right decision at the right time.

The manufacturing model maintains all manufacturing process information for all products whereas the product model needs only specific manufacturing process information for product fulfilment. For this reason, the authors have proposed an interaction from the product model to the manufacturing model. This means that the communication between the product properties and the global manufacturing capabilities can only begin with product information.

These data models have been applied to an industrial case.

3. Information system for DF: Info SIM

Logical model

From the information conceptual model presented in the previous session, we have developed an information system called "SIM Info". It is able to manage the information necessary to perform simulation in DF, and information resulting of these simulations. Indeed, from this conceptual model we propose a logical model in UML, used to the development of the information system Info SIM *(***Figure 3***)*. In **Figure 3**, we note that the logic model takes into account information related to the product *(Product Information)*, to the production process *(Production information)*, and to simulation *(Simulation information)*, as well as the interaction between these informatio. This corresponds to the conceptual model presented above. *Product Information* part of the logic model also considers the possibility of adding documents related products *(attachments)*, and inserting remarks related to the return of simulation experiences. *Graph Control* part of the model is used to control the generation of information on the product, the production process and simu-

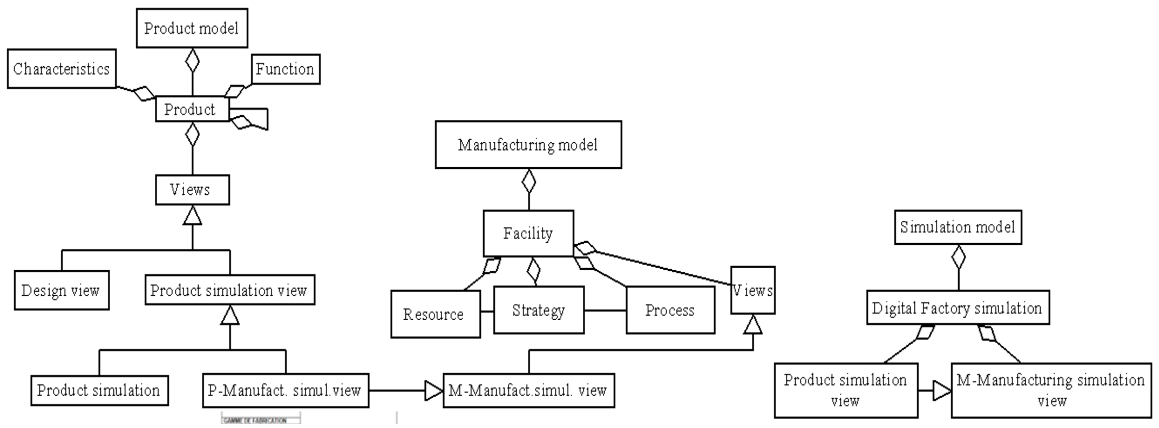

FIGURE 2. *Information integration between views of product, manufacturing and simulation models (Ayadi et al., 2011).*

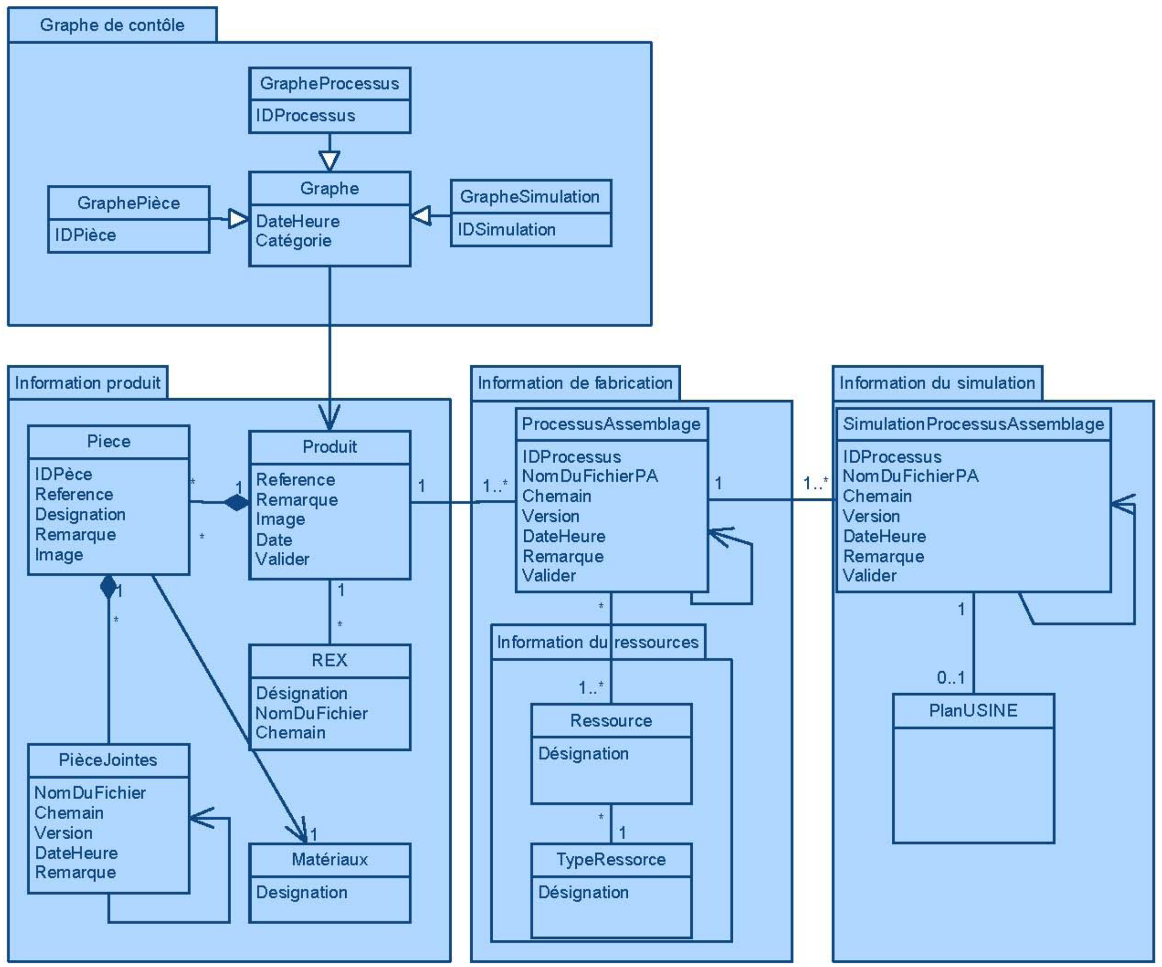

FIGURE 3. *Logical Model of Info SIM.*

lations in the information system Info SIM. It will be detailed later.

Info SIM

From the logic model presented in **Figure 3**, Info SIM has been developed using Windev. WinDev is designed to develop applications, mainly oriented data, and it handle many data base management systems *(MySQL, Oracle, SQL, etc.)*.

In the first screen after booting Info SIM, the user can create a new project by inserting a title and a description, or the user can look for an existing project *(**Figure 4**)*.

After, three types of information can be inserted or accessed through different tabs at the top of the window: information about product, part or equipment *(Part Information)*, about the production process *(Process Information)* and about the simulation *(Simulation Information)*. In these tabs, users find information related to references, descriptions, comments, and they can attach documents related to each type of information. In the *Simulation Information* tab, users have access, for a product, to information about its manufacturing process and about the simulations made. In addition, the date and time of information creation are saved so that Info SIM can manage different versions of information. A fourth tab, called *Consultation*, provides users information to better manage projects. This information is generated by Info SIM, and are accessible from two buttons: *Control Graph* and *Validation*. In the *Control Graph* option *(**Figure 5**)*, the user finds a schedule that shows when each information has been generated *(day, date and time)*, which allows a better analysis of the project. The blue color represents product or part information, the yellow color represents manufacturing process information, and the red color represents simulation information.

In the Validation option *(**Figure 6**)*, the user can find all files that related to different simulations associated to a product. In this window, the responsible of the simulation can validate and / or add comments and notices. When all of product simulations are validated by the respective responsible, Info SIM automatically validates the project.

Finally, the main features Info SIM are:

- Link product and part information. This relationship between information promotes the notion of information reuse which can save time spent in product development projects;
- Link product information to its production processes information;
- Allow quick access to product/part information by two search engines using either references, materials or designations.

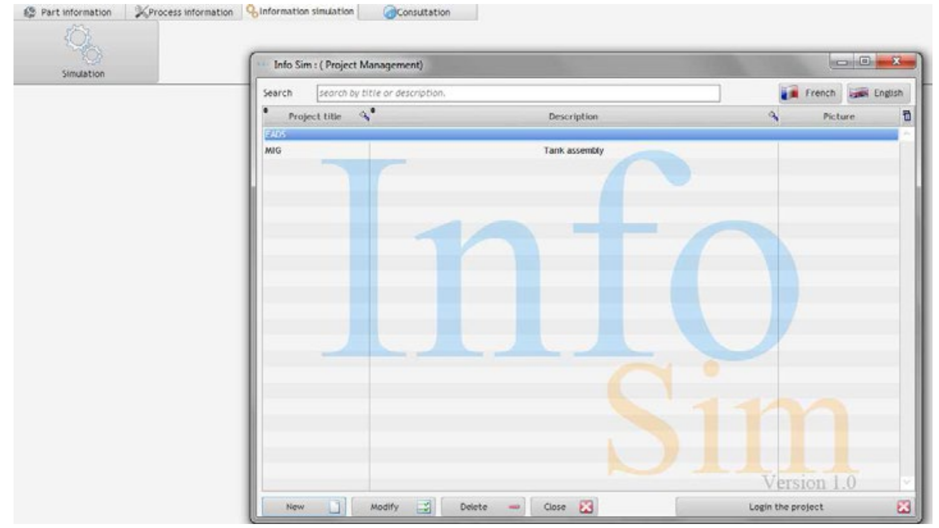

FIGURE 4. *Initial window of Info SIM*

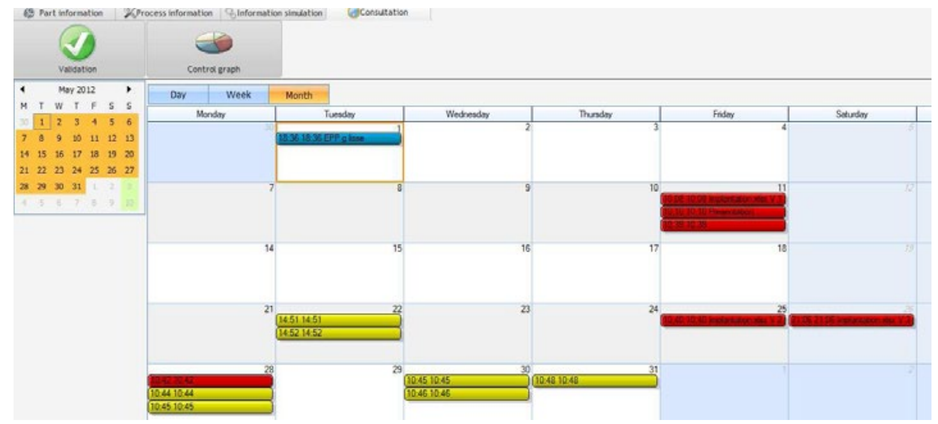

FIGURE 5. *Control Graph of the information system Info SIM*

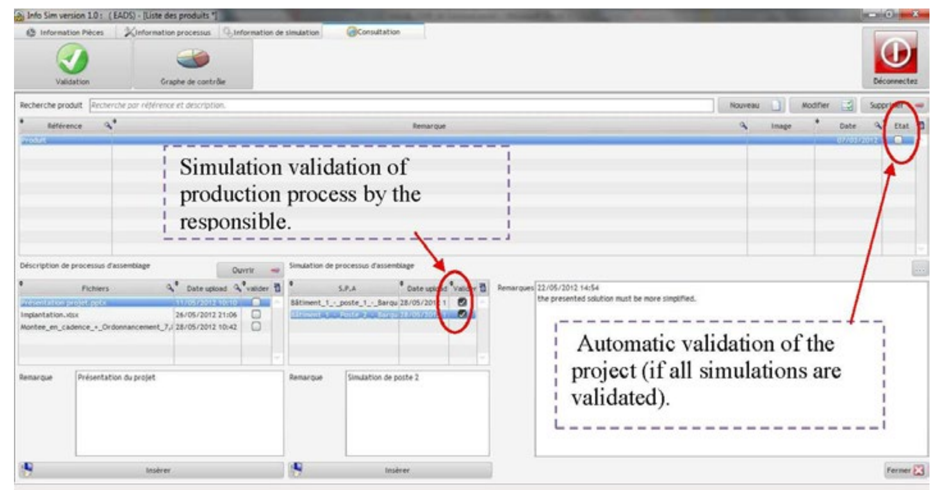

FIGURE 6. *Simulation validation in the information system Info SIM*

- Allow the addition of several file types (all existing extensions: pdf, doc, ppt, dwg, avi) to product information and manufacturing processes tabs;
- Link simulation information to production process information.

Thus, Info SIM enables integration of product information, production processes and simulation. Through this integration, users, who can be part of different departments of the company, have a better visibility of product development project progress, and access different information allowing them to make better decisions and earlier.

4. Conclusion

In this paper, we proposed an information system for managing information in Digital Factory. Its aim is to address the problem of lack of integration between product, production processes *(and resources)* and simulation information. We believe that this tool will help users, participating in the product development project, use simulation tools more often and earlier in product development projects, allowing a better decision about the product. As perspectives of this work, we should apply Info SIM an industrial case. Indeed, two applications are in progress and they concern a simulation of an assembly process of a metallic tank for a chemical product; and an assembly process of a plane section. In addition, we will enhance Info SIM functionalities, taking into account information related to the resources used in each simulation, and implementing the REX *(Return of Experience)* function. Through the REX, Info SIM can capitalize experiences related to the construction of each simulation and analysis results. We believe that knowledge reuse is a key point to make future projects more agile and robust design, and be able to tranform individual expertise to knowledge shared inside the group.

authors

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