Proposition of a Conceptual Model for Knowledge Integration and Management in Digital Factory

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Abstract. The key of successful industry is to satisfy the customer requirements at the perfect delay with improved quality and cheaper price. In this context, Digital Factory is known to test and validate the couple product-production system during the Product Development Process (PDP), with the usage of production system simulations; therefore we can use an information system like InfoSim to integrate and manage all information related to product, process and simulation in this context. But with this huge amount of information, an actor of PDP may be confused to make a good decision at this particular stage. Thus, there is a lack of knowledge capitalization and sharing between PDP actors. In this research work, we propose a conceptual model dedicated to the management and capitalization of knowledge and experiences of previous projects in the context of Digital Factory.

Keywords: Knowledge · Capitalization · Management · Digital factory · Information system

1 Introduction

In recent decades, a large number of companies sought to value the intangible investment (research and development, training, advertising, organizational methods, etc.) and, in particular, their capital knowledge. This capital is then re-used in different situations in order to reduce the costs and the times of development [2].

Among such knowledge-based situations, 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 [3]. In particular, Digital Factory (DF) was born to design and simulate production systems throughout the product design process. It can be defined as a set of software tools and methodologies allowing the design, simulation, initiation and optimization of production systems [4–6]. Despite the high performance of simulation tools in digital manufacturing [7], there is a lack of deployment related to [1, 8] the intrinsic

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complexity of DF but above all, the absence of integration of information and knowledge from previous projects of production systems simulation.

The management of information and knowledge between the product and its production process, including data related to resources, is so essential. Indeed, the solution adopted for product development is to integrate different types of information and knowledge (product, process and resources) as soon as possible to make the right decisions at the right time [1].

Most researchers have focused on the product knowledge whereas some others have interested on the process planning. Thus we identify the following research gap: how to manage and control all knowledge types in the context of DF, including product, process, resource and DF simulation one.

Based on previous research works that contribute to InfoSim, a framework dedicated to DF data and information management and control [1], the main objective of our current research work is to model and implement inside InfoSim a framework for the management and the control of knowledge for digital design and production, allowing to manage and improve the possible DF simulations, and also focusing on knowledge capitalization and experience feedback towards new DF projects.

The article is structured as follows. Section 2 presents a study of the literature: first, we define knowledge management then we analyze existing methods of knowledge capitalization. Section 3 describes the conceptual model of the proposed framework which it will be validated with case study in Sect. 4. Finally, Sect. 5 presents the conclusions and perspectives.

2 State of the Art

2.1 Knowledge Management

In 1991, Tom Stewart advised the company to focus more on their knowledge than on their material goods: « Intellectual capital is becoming corporate America's most valuable asset and can be its sharpest competitive weapon. The challenge is to find what you have -and use it » [9].

Baizet defines the knowledge like refined, synthesized, systematized information, or like information associated with a context of use [10]. With this definition it is clear that there is a difference between the words: data, information and knowledge, while Tsuchiya differentiates these terms with this definition: « Although terms "datum", "information", and "knowledge" are often used interchangeably, there exists a clear distinction among them. When datum is sense-given through interpretative framework, it becomes information, and when information is sense-read through interpretative framework, it becomes knowledge » [9].

Most of the authors, like Grundstein, Nonaka and Takeuchi, divide knowledge into two kinds: explicit knowledge and tacit knowledge (know-how) [11, 12]. Explicit knowledge refers to knowledge transmitted through a "formal and systematic" language [13]. It is a technical or academic data or information that is described in formal language, like manuals, mathematical expressions, copyright and patents [14]. Tacit knowledge refers to know-how that is difficult to formalize and communicate and can't be transferred that by the willingness of people to share their experiences, it is usually acquired over a long period of learning and experience [11, 13].

Ermine assumes "knowledge management is the goal of formalizing tacit knowledge in order to make mobilized and operational at the level of the entire organization" [15]. Then Nonaka and Takeuchi represent the transformation mechanisms involved between explicit and tacit knowledge (as shown on Fig. 1(a)) [12].

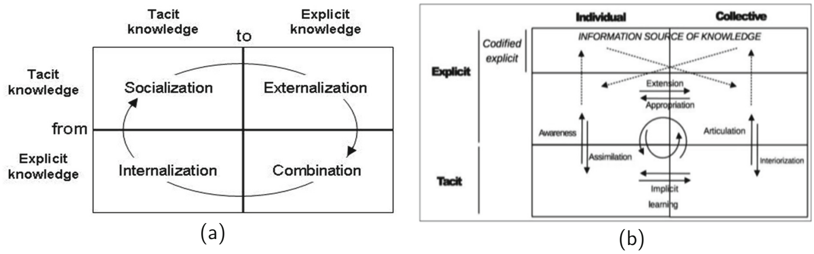

Fig. 1. The transformation mechanisms between (a) tacit and explicit knowledge [12] (b) individual knowledge and collective [16]

Skyrme defines "Knowledge Management is the explicit and systematic management of vital knowledge and associated processes including the creation, collection, organization, dissemination, use and exploitation of knowledge. KM requires the passage of personal knowledge to collective knowledge that can be shared widely in organization" [17]. With this definition Baumard represents the individual and collective knowledge transformation mechanisms (as shown on Fig. 1(b)), so he completed the model of Nonaka and Takeuchi [16].

Ramon defines "knowledge management is the process through which an enterprise uses its collective intelligence to accomplish its strategic objectives" [18]. Like in [13], we can summarize clearly the aim of the KM operation with: "Getting the right knowledge to the right people at the right time in the right size without being asked". And the expression "knowledge management" covers all the managerial actions aiming to answer the problem of capitalization of knowledge in general [11].

McMahon assumes that there are two approaches in KM: Codification which focus on the reification of knowledge so it focus only on explicit knowledge and personalization which focus on individuals as holders of knowledge and which it justifies to take into account the tacit and explicit knowledge [19].

Knowledge Management allows companies to train their memory by the integration, sharing and reuse of all knowledge (tacit and explicit) of PDP actors which are related to product, process, resource and simulation in an information system. It is the solution of several problems (such as the complexity of DF, the amount of simulation data and the variety of viewpoints) in Digital Factory. Then it allows companies to store the best simulation results for reuse in another project with all viewpoints.

In order to propose a conceptual model for the integration and reuse of knowledge in DF (tacit and explicit knowledge of product, process, resources and simulation), we present, in the following section, the definition of Corporate Memory and some methods of knowledge capitalization presented in the literature.

2.2 Corporate Memory and Knowledge Capitalization Methods

A corporate memory is an explicit, disembodied, persistent representation of the knowledge and information in an organization [20]. It includes not only a "technical memory" obtained by capitalization of its employees' know-how but also an "organizational memory" (or "managerial memory") related to the past and present organizational structures of the enterprise (human resources, management, etc.) and "project memories" for capitalizing lessons and experience from given projects [21].

There are several methods of knowledge capitalization: some of these methods have been designed to define a project memory, others are more general.

We focus in this report on classical methods combining the technical, human and organizational aspects which can be presented according to two approaches:

- Corporate memory itself like methods REX (method of experience feedback), MEREX (Methodology and experience feedback) and CYGMA (Lifecycle and management of Jobs and Applications), that consider six categories of industrial knowledge with jobs' reference. Workshop FX results from work of social sciences which aim at using the actor's experience of the industrial process to create enterprise knowledge;
- Models resulting from the knowledge engineering like KADS (Knowledge Acquisition and Design Structuring), CommonKADS (Common Knowledge Acquisition and Design Support), KOD (Knowledge Oriented Design) and MKSM (Method for Knowledge Systems Management) associated with its extension MASK (Method of knowledge analysis and structuration), Componential framework etc., which present various conceptual models interacting to each other [22].

These methods are generic and cannot cover our needs. In the next section we present our conceptual model dedicated to the integration and reuse of corporate knowledge. To do this, we chose UML as a tool for presentation of corporate knowledge.

3 Conceptual Model

Our proposed model is attached to the conceptual model of InfoSim (Fig. 2), which is an information system dedicated to manage information on simulations in digital factory, its objective is the integration of product's information, production processes and simulation [1].

In Fig. 2, DF entity that covers the main classes of the model Product Component, Process Component, Resource and Simulation. This class can also be associated to a file, version and to an experience that can be shared for future projects. One or more versions of Product, Process, Resource and Simulation can be considered in a DF Project which is associated to a control Graph [23].

The conceptual model of knowledge is depicted in Fig. 3. In this model the knowledge entity class can be used in Digital Factory project of InfoSim. This class includes the two main classes of the model: General Knowledge entity Project and Knowledge entity which is created in Digital factory project of InfoSim. In the attribute of these classes we can also specify the type of knowledge like tacit or explicit.

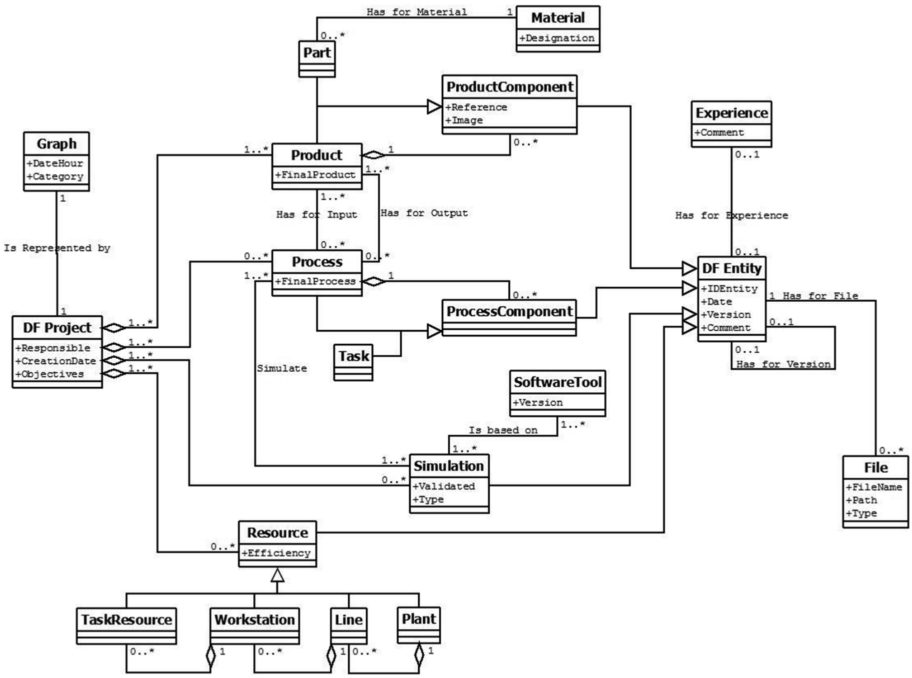

Fig. 2. Conceptual model of InfoSim [23]

Every knowledge element contains its own content (Knowledge content class which gives a more detailed description of what is contained in the element) and is embedded in a specific context (Knowledge context class which depicts the comprehensive environment of the knowledge element for a better understanding.

We define a Knowledge context class with the all of attributes of the classes (View point of designer, manufacturer or simulator and knowledge creator), like a date, place and support.

In our modelling the knowledge content class is linked with the knowledge entity class through the composition relation, because if we remove the knowledge all its contents will be delated.

The knowledge content (which contains the attributes like the name, the file, the usage etc.) is attached to digital factory of InfoSim. It can be the knowledge of product, process, resource, simulation, materials or project knowledge which they are linked. Indeed a product is linked to a material and a Process. This last class require resource which can be human or machine, and human resource can also has a view point. Finally the simulation needs to know the resource and process to obtain concrete results. The classes of product, process and simulation are attached with the classes of product component, process component and simulation of InfoSim.

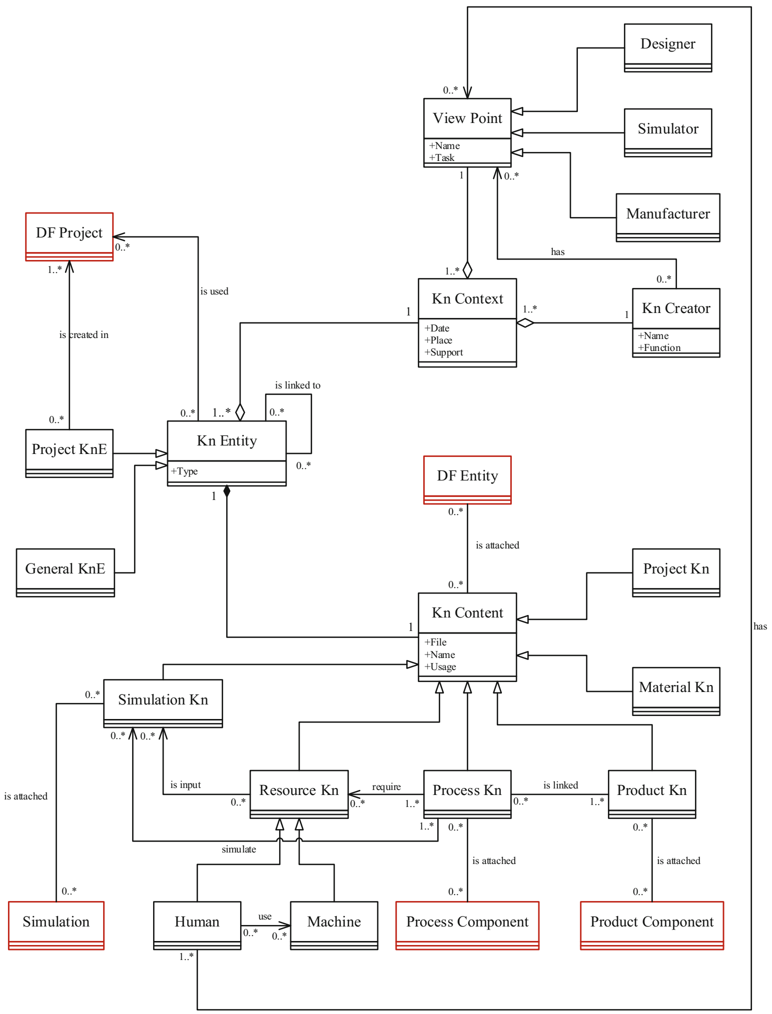

Fig. 3. Conceptual model

4 Case Study

Our case study concerned the manufacturing of floating roof tank. The purpose of this case is to validate our conceptual model for integration knowledge in Digital factory. It has two general parts: the creation and the usage of knowledge.

4.1 Design Process

The design phase is the activity of developing the best solutions from a given need.

The first phase contains several steps. In each steps we can used general knowledge and results of previous projects and we can obtained project knowledge. Indeed every company has a general knowledge that it can be used in several projects and helps actors to make the right decision in the right time. Moreover each project can be used in others projects.

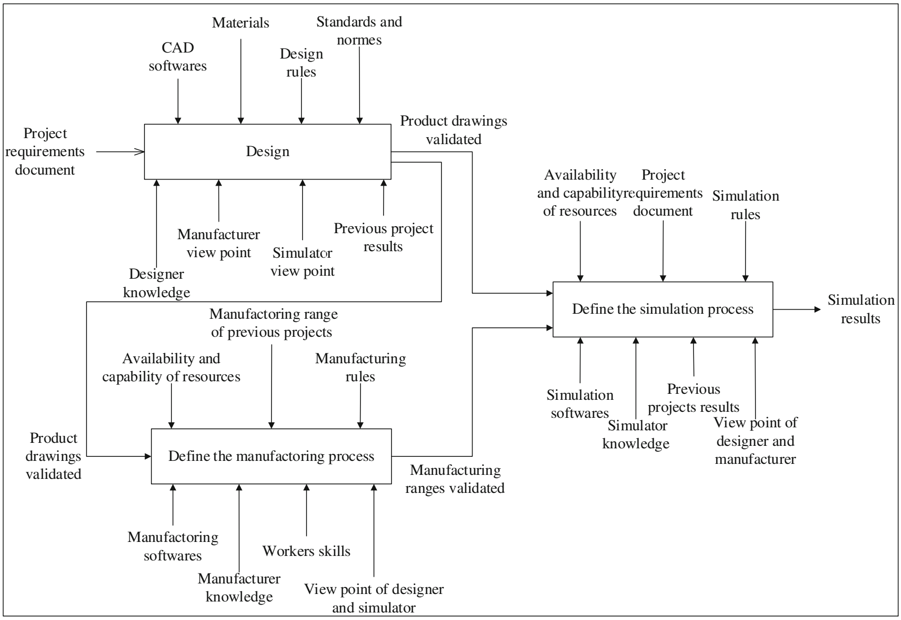

Fig. 4. Digital manufacturing process of tank in digital factory

Figure 4 shows the knowledge that we need to know during the design phase like data sheet materials, the standards API650, software Tutorials, drawings of standard pieces, designer knowledge, view point of manufacturer and simulator and the results of previous projects. Each of this knowledge has a content that is product knowledge and has a context which can be the viewpoint of PDP actor and the creator. Moreover, all results of this project will be a project knowledge that we will use in the future.

4.2 Digital Manufacturing Process

A range of manufacturing is a document that lists all phases of part development. It is noted step by step the evolution of part manufacturing. According to studies conducted by the company, we can divide the manufacturing phase into two main groups:

- Part transformation process
- Assembly process

Figure 4 shows the knowledge needed to know manufacturing duration phase like all company resources (ability skill and experience of human, features and technical data of equipment), workers knowledge in video format, manufacturer knowledge, a point of view of the simulator and designer, manufacturing range of previous projects. Therefore, we used the corporate knowledge (General and Project) which are related to resource and process (content) then we obtained project knowledge. This knowledge has also a context like the creator and viewpoint of simulator and designer.

4.3 Simulation Process in Digital Factory

The simulation is used to study the physical flows (parts, materials, tools, etc.), informational in the workshop (Manufacturing orders, assembly order, etc.) and the availability of resources (operators, machine, conveyors, etc.). It is used to evaluate and compare several scenarios (Table 1).

Figure 4 shows the knowledge that we need to know during the simulation phase like the knowledge simulator, view point of designer and manufacturer, previous project results, tutorials of simulation software etc.

During this phase we obtain the simulation results for the best solution in the project knowledge and we can also put the other results simulation in the general knowledge. These results can help actors to make the right decisions in other projects (Table 2).

Table 1. Project knowledge.

Kn Content \ Kn Context		Creator	Designer Viewpoint	Manufacturer Viewpoint	Simulator Viewpoint
Product	Material	×	×	×	×
	Study and calculation	×	×	×	
	Part list	×	×	×	×
	Part Simulation	×	×	×	
	Product list	×	×	×	
	Product simulation	×	×	×	
Process	Part transformation process	×	×	×	×
	Assembly Process	×	×	×	×
Resource	Worker list	×		×	×
	Machine list	×		×	×
Simulation	Results simulation	×	×	×	×

5 Conclusions et Perspectives

In this study, starting from the concept of knowledge Management, we propose a conceptual model that supports Knowledge integration in digital factory. Our model allows the creation, the sharing and the reuse of knowledge earliest during the PDP. It allows also the integration of all explicit and tacit knowledge of PDP actors and

Table 2. General knowledge.

Kn Content \ Kn Context		Creator	Designer Viewpoint	Manufacturer Viewpoint	Simulator Viewpoint
Product	Material	×	×	×	×
	Standards	×	×	×	×
	Standards Parts	×	×	×	×
	Software tutorials	×	×		
	Designer Knowledge	×	×		
	Design rules	×	×		
Process	Manufacturing videos	×	×	×	×
	Manufacturer Knowledge	×		×	
	Software tutorials	×		×	
	Manufacturing rules	×		×	
Resource	Worker list	×	×	×	×
	Machine list	×	×	×	×
Simulation	Results simulation	×	×	×	×
	Software tutorials				×
	Simulator Knowledge				×
	Simulation rules				×

workers. In our model, we proposed that every company has two types of knowledge: project knowledge and general knowledge. Each of this knowledge has a context and content. Else we linked our model with the InfoSim model. Indeed during the creation a new project we need to know all company knowledge (project and general knowledge) to make the right decision at the right time. Furthermore project knowledge is created by the digital factory project. Then, an industrial case study has been presented for illustrating the applicability and validity of the proposed model. We described in our case all the knowledge that we need during the phase of design, manufacturing and simulation and all knowledge which it can be obtained during a project development.

Various prospects for future work have been proposed for this conceptual model. The aim of this work will be to enable the model to support the integration and reuse all knowledge in digital factory. Thus we will implement and test our model in the information system InfoSim.

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