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Towards Management of Knowledge and Lesson Learned In Digital Factory

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Abstract:In a world characterized by increasing competitiveness, delivering a good product as soon as possible and increasing complexity of the product, the old method did not satisfy the needs of companies. In this context the Digital Factory is a solution that is based on the simulation and analysis of all the process of product production to reduce the cost of prototyping and physical testing. But, despite his performance there is a lack of deployment related to the lack of integration of information, knowledge and feedback.

So in this article we proposed a model that includes the integration of all the information, knowledge and Lesson Learned.

Key words:Digital Factory, Lesson Learned, Knowledge Management, simulation, information system.

1- Introduction

To evolve in the current economic environment, companies must achieve increasingly higher performance levels. To achieve this aim, they are showing adaptability and responsiveness, while continually seeking quality improvement. In order to survive, organizations are challenged to faster design, develop and produce cheaper products that meet user's requirements. But it is not enough to make the right product or good service, it must be better than the competition provides.

In this context of collaborative engineering, the digital prototyping (based on the concepts of digital models representing the product, its physical behaviour, and its manufacturing process) is a solution to test and validate a product earlier in its lifecycle [H1]. The simulation, associated to these digital prototypes, becomes an essential tool to avoid unexpected problems occurring during upstream phases of the product lifecycle, and so it allows reducing time spent in the product design project by helping the decision making process.

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 [BM1], [CM1], [K1]. 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.

Despite the high performance of simulation tools in digital manufacturing [CK1], there is a lack of deployment related to [AC1], [NL1]:

- The intrinsic complexity of DF, due to the different levels of detail co-existing (from the operation on a specific station to the global supply chain) [WE1] and to the variety of simulation type (prescriptive vs. based on events) [AC1],
- The absence of integration of information and knowledge from previous projects simulation of production systems,
- A lack of exchanged information with other enterprise services and their information systems, especially ERP and PDM.

The management of information and knowledge between the product and its production process, including data related to resources, is 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.

As a consequence, the main objective of our research work is to model and implement a framework for the management and the control of data, information and knowledge for digital design and production, allowing to manage and improve the

possible simulations of DF, and also focusing on knowledge capitalization and experience feedback towards the new Digital Factory projects.

The article is structured as follows. Section 2 presents a study of art state: first, we define digital manufacturing and information systems then knowledge management. Section 3 describes the proposals. Finally, Section 4 presents the conclusions.

2- State of the art

2.1 – Digital Factory

By definition, Digital Factory is attached to the simulation of the production system according to a product development process. 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 [HH1].

As a consequence, the notion of **granularity** is important in order to define a simulation easy to develop and likely to obtain concrete results, according to the amount of information and its maturity known at a given time of the PDP. For instance, the authors of [BF1] propose a three-stage approach to equilibrate the simulation effort with expected precision of simulation results:

- Calculation: approximate calculation of the system capacity
- coarse simulation with a custom standard modules based on standardized modules approach
- Detailed simulation, specific aspects of the production system are examined by exact models

Generally a detailed simulation requires a significant development time, or a coarser simulation does not take into account the important details. It may prove necessary to eventually leave the choice of simulation detail level based on actual needs of product's development process actors [AC1].

In this context, the projects Digital Factory and Digital Factory 2 [B1], from the SYSTEM@TIC Paris-Region cluster, have proposed a structured representation of the Digital Factory on six levels of details, corresponding to an aeronautic vision of the extended enterprise (figure 1).



Figure 1: Different layers in the Digital Factory [B1].

These layers correspond to specific needs for the design and simulation of the production system behaviour, and so to specific actors of the production system development process, with their own tools and methodologies. For example, at level 1 or 2, the objective can be to determine the physical supply flows inside the extended enterprise. At level 3, the objective can be to validate a physical layout inside the plant and a line rate. At level 5 or 6, the objective can be to validate the settings of a manufacturing program in the production environment (robots, CNC machining, etc.).

Digital Factory is based on a large number of heterogeneous simulation tools based on different levels representation of the production system. It is therefore possible to perform a simulation of flow line production to determine inventory levels necessary to satisfy the needs of customers, or the simulation of a machining operation on a workstation, for conceive and validate the offline programming of the digital control.

For each level of detail, there are specific simulation tools corresponding to specific actors. In figure 2, two principal families of simulation tools which can be used in the Digital Factory [CL1]:

- **Based simulation of events:** it is constituted by elements that react to certain events
- **Prescriptive simulation:** it describes the behaviour of the production system over time

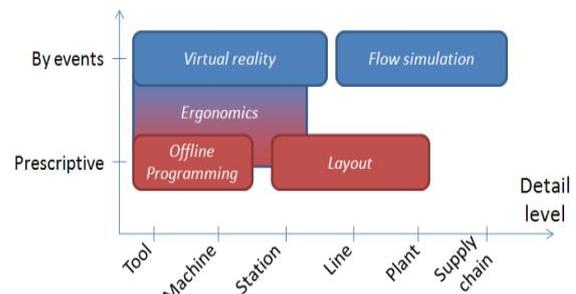


Figure 2: Positions of the simulation major types [CL1].

2.2 – Information System for Digital Factory

Based on this diversity of software tools and simulation objectives, information management between the product and its production process including data related to resources is so essential and requires a specific **Information System**.

An information system can be defined as a set of individual or collective instruments participating in the process of information management in the organization [R1]. Another definition has been proposed by [C1]: “an information system is a set of resources organized for the collection, storage, treatment, maintenance, use, sharing and dissemination, making available, display or transmission of information”. Resources are defined as personnel, equipment, budgets and information technology. Thus, the main goal of the information system is to provide every actor in the organization with all the information about its current or previous situation.

In this context, the “perfect” information system should be

dedicated to the integration and the management of information related to the product/process simulation throughout the first phases of product lifecycle. Such information system must be able to integrate different **views** (design, production and simulation) [GY1], [KV1], from different information systems used in design and production phases.

The main existing IS are actor-oriented, i.e. defined for a particular point of view. In the context of our study, we classified them into three families:

- IS dedicated to the product design process and especially the **Product Data Management** (PDM) [EG1], [DC1],
- IS dedicated to the production process and especially the **Enterprise Resource Planning** (ERP) [KA1], [BM2],
- IS dedicated to the simulation management and especially the **Simulation Lifecycle Management** (SLM) [PR1], [L1].

Moreover, few approaches [FH1] and some software (for instance DELMIA Process Engineer from DassaultSystèmes or WindchillMPMLink from PTC) have been proposed in the context of DF, namely the Manufacturing Data Management (MDM) systems.

Despite the development of such IS, these systems are focusing on specific areas of the company. Until now, there is not an IS covering all information necessary for overall product's decision making, in addition there is a lack of interoperability between these different tools.

InfoSim is a IS dedicated to manage information on simulations in digital factory [AC1]. Its objective is the integration of product's information, production processes and simulation.

Thus, InfoSim enables to integrate product's information, production process and simulation. Through this integration, the actors who can be part of different departments of a company have a better visibility of the project evolution of product development, and access to different information, which will help them make better decisions in soon as possible.

Nevertheless, InfoSim only allows the integration of data and information related to the product, process and simulation but not the integration of knowledge and experience from previous projects. So there is a lack of exchange and transfer of knowledge between all actors PDP.

2.3 – Knowledge Management for Digital Factory

A lot of companies sought to valorise intangible investment (research and development, training, advertising, organizational methods, etc...). And, in particular, their knowledge capital. Knowledge has become a major concern for companies and organisations; knowledge mastery replaces, at least in part, to industrial mastery [BT1], [L2],[U1].

The **information** is considered as treated **data**, it is an aggregation of data that have meaning, which implies that the facts were placed in a context which was organized for a goal [E1], [T1]. **Knowledge** is based on contextual, relevant and exploitable information. Knowledge is information with

additional details regarding how it should be used or applied.

Knowledge is unavailable directly: it is obtained by the interpretation of the information deduced from the analysis of data. Data are available to an organization in the form of observations, calculation results, etc. The interpretation, abstraction or combination of these data leads to the production of information. Finally, knowledge is obtained through experience and learning of this information [CR1].

In this context, literature expresses two different types of knowledge: explicit one and tacit one.

Explicit knowledge refers to knowledge transmitted through a "formal and systematic" language [L3]. It is the result of an extraction of a knowledge part of enterprise memory (rules, stored experiences and feedback from experience) [FB1].

Tacit knowledge refers to know-how that is difficult to formalize and communicate and can not be transferred that by the willingness of people to share their experiences, it is usually acquired over a long period of learning and experience [CR1], [L3]. It is owned by actor useful in completing the task and not in shared memory. This part of the knowledge comes from learning, intuition and experience. Unfortunately, this knowledge is also lost with the loss of the person or team of the organization.

Experience is defined as "an event experienced by a person that may bring a teaching" [R1]. This experience of an individual or group of individuals, resulting in one or information related to a given context. This information therefore includes:

- The situation in which the event appeared
- The description of the event
- The lessons learned by the individual or group who experienced it

Experience is the result of the implementation of know-how in previous projects. It specifies the use of knowledge well as the result of use in qualitative term. We thus find sometimes the terms of positive experience (or best practice) and negative experiences (mistakes to avoid) [FB1].

The Lesson Learned is the result of an analysis of the experience and aimed at to discover the cause of the judgment on the activity and designed to lead to a change in the behaviour of individuals [FB1].

Today companies of all kinds and all sizes are interested in the preservation of knowledge and methods of **Knowledge Management** (KM). Grundstein in [G1] defines KM as the management of activities and process supposed to amplify the use and creation of knowledge inside an organization according two complementary purposes, strongly connected: a legacy purpose and a purpose of sustainable innovation. These methods so aim to capitalize knowledge and experience available within a company and ensure their transmission. 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" [L3].

So, KM leads to the usage of a set of tools and methods to better use the knowledge and knowledge potentially available to an organization with the aim to improve storage capacities, learning, collaboration and innovation through better management of its intellectual and informational assets.

According to [ML1], two main approaches exist in KM: **codification** approaches, which focus on the reification of knowledge, and **personalisation** approaches, which focus on individuals as holders of knowledge.

Personalisation approaches cover the various knowledge transformation mechanisms as applied within an individual or between individuals (Figure 3) when they are freely expressed and lead to solutions oriented towards practices communities [AR1] as well as CSCW-type (Computer-Supported Collaborative Work) tools [K2]. Codification approaches cover the elicitation of knowledge in a controllable form beyond the actual individual and are, for the most part, based on information and communication technology [CH1].

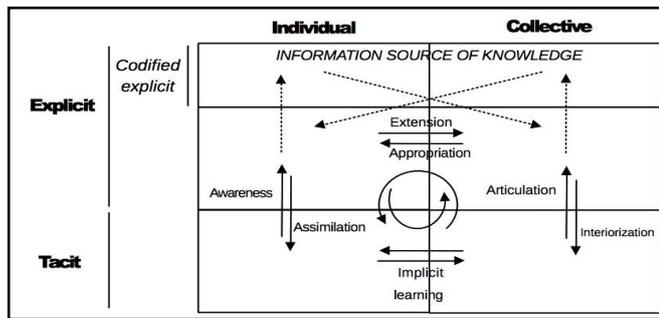


Figure 3: Extension of knowledge transformation mechanisms in an encoded environment [B2].

In this context and according to the type of KM approaches chosen, several types of tools have been developed for various applications [CR1], [L2], [VB1]. These tools allow you to manage all the knowledge of the organization actors, in order to have a better exploitation. One can cite as KM tools:

- General Tools and methods for the formal and informal exchange of knowledge
- KM Tools for knowledge capitalization
- KM tools for knowledge sharing
- KM tools for retrieving knowledge
- KM tools for query

In the literature, we find that knowledge management and simulation are separate, but in reality they are inseparable in practice. The data obtained from the simulation model after testing and analysis can generate new knowledge.

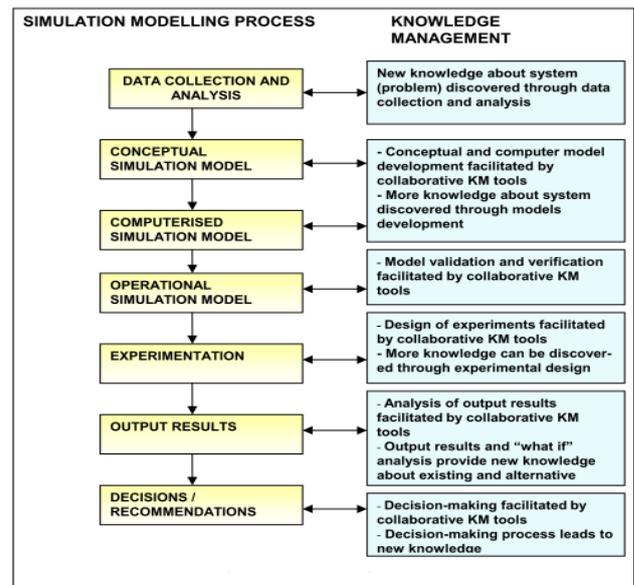


Figure 4: Interdependencies between simulation modelling process and KM [HV1].

Figure 4 shows how knowledge management is linked to the simulation process.

During these processes, new knowledge can be discovered and can be used for problem solving and decision making. Simulation models can be used to study the processes of knowledge management, knowledge flows and processing activities of knowledge, to simulate missing data necessary for the management of knowledge, or to evaluate alternative models of strategies knowledge management [HV1] and the effect of new knowledge management practices on business processes [LH1]. Figure 5 shows them.

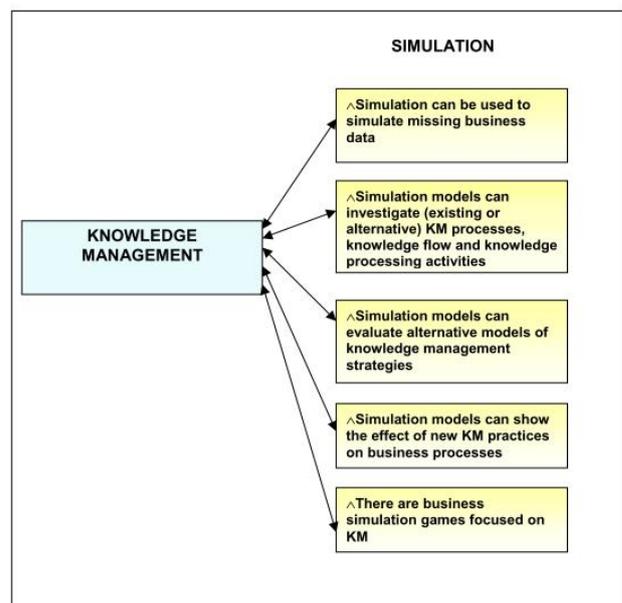


Figure 5: Simulation models in the context of knowledge management [HV1].

The use of knowledge management with simulation has several advantages, which is why the researchers are interested in combining these two approaches.

Edwards and Alifantis presented a simulation model as part of the knowledge elicitation process in a project simulating maintenance operations in an automotive engine production facility [EA1].

Canals, Boisot and MacMillan develop an evolutionary agent-based simulation model derived from a knowledge-based theoretical framework, and use it to explore the effect of knowledge management strategies on the evolution of a group of knowledge-intensive organizations located in a given geographical area [CB1].

Srinivasan and Horowitz propose the use of simulation as a tool for assessing the quality of an analytical knowledge management model constructed using a technique called Root Causes Analysis (RCA) Modelling, generically known as Structural Equation Modelling [SH1].

Thus, the digital factory needs a model that uses the applications of knowledge management tools in the study of process simulation.

3- Propositions

All companies are based on the learning capacity of its staff. The lessons learned and the transfer of knowledge is the keys to this success.

Proposition 1: An information model that can capitalize on and manage knowledge of design, production and simulation. The model is based on the collection and storage of information, after we will interpret this information to create knowledge of the company.

Our model will contain transformation knowledge, specific knowledge and lesson learned.

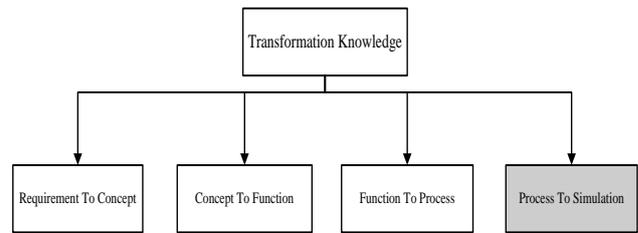


Figure 7: Some top-level classes of transformation knowledge.

Specific knowledge is the specific knowledge resources (machines, tools, etc.) that will transform product view information to manufacturing view information and validate the operation, such as specific knowledge of machine will transform information of the sub-functional and assembly views of to the machining view and validated against machining view-point considerations.

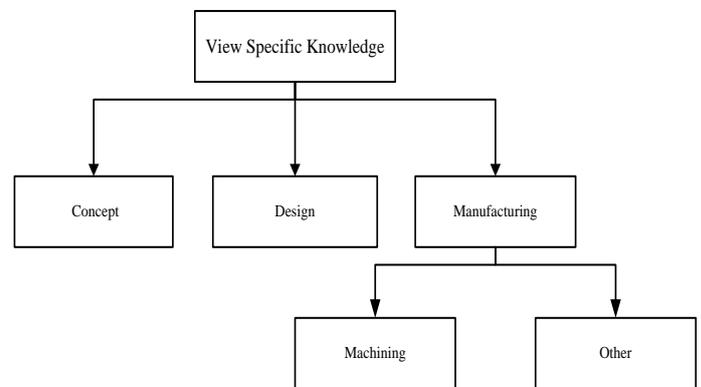


Figure 8: Some top-level classes of View Specific knowledge.

Lesson Learned is the knowledge created through the collection and interpretation of information which can be validated with simulation [AC1], the results of interpretation of this information either by validation or not, will create new knowledge which is crucial in new projects.

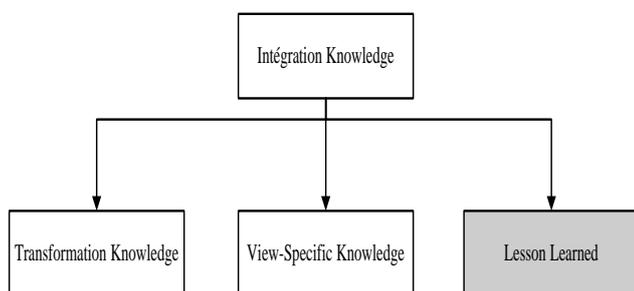


Figure 6: Some top-level classes of Integration knowledge.

Transformation knowledge is knowledge that allows the navigation information from a phase to another: requirement to concept, concept to function, function to process and process to simulation, it allows the transformation of information between views such as the functional view information transformed to assembly view information from explicit knowledge.

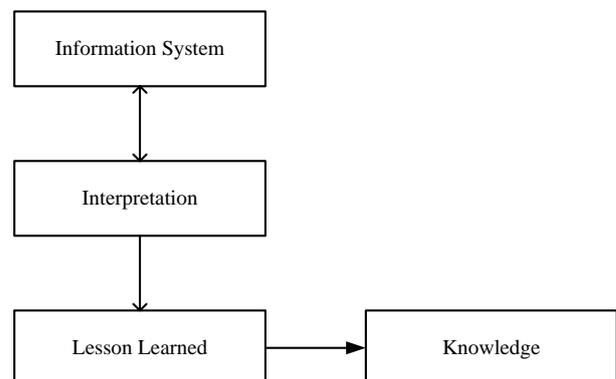


Figure 9: knowledge creation from Lesson Learned.

Class Lesson Learned is divided into two sub-classes: sub-class reserved for results and sub-class reserved for errors.

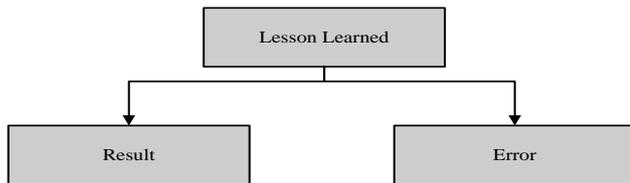


Figure 10: Some top-level classes of Lesson Learned.

4- Conclusion

The old methods for product development didn't satisfy the needs of companies that are summarized in the implementation of an innovative and fast development cycle. So in this paper we showed the use to other method which is the management of knowledge and feedback. After recalling the meaning of certain central terms of this method we proposed a model that allows the integration of all information, explicit and tacit knowledge and feedback to facilitate the transformation of information between all actors of PDP and the validation of process.

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