Toward a cognitive based approach for knowledge structuring

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***Abstract*—Competitiveness led factories, today, to be much more careful with their product development process, more accurate with their human resources and involve a diversity of actors such as operators, technicians, engineers, etc. creating heterogeneous knowledge domains. In this paper, we aim to present a comprehensive explanation of an approach regarding knowledge extraction and structuring in the factory. We begin our paper with an overview about the context of our research proposal. Then, we explain different constraints to take into account during the process of building our model.**

Keywords—Knowledge structuring; Knowledge Extraction; Cognitive InfoCommunication, Man-Machine Interactions; Working situation.

I. Introduction

Regarding the increasing of products complexity and customers desires in product development field, the need for knowledge and expertise in production lines become an important key factor to handle quality and efficiency requirements. Production environment requires assistance tools that enable retrieval, reuse, structuring and representation of the entire product and process related knowledge.

Visions about the factory of the future affirm that future production lines will be characterized by learning capability and decisions support in all stages of the process chains involved [1]. The aim of such propositions is to achieve higher manufacturing outputs by integrating knowledge modules into the engineering systems concerned in the factory mainly thanks to digital tools. Despite the evolution of digital tools in the factory, the role of the human being in the product lifecycle development is not insignificant. The main challenge in today's production systems is to provide factory actors with assistant tools that help them to work more efficiently and to react quickly in front of critical working situations. In some practical situations, factory actors need to get information and to acquire more knowledge to perform better in front of difficult tasks.

The most common example of digital assistance tools are Decision Support Systems (DSS). DSS evolved in a significant way thinks to the parallel evolution made on information and communication technologies. This evolution results the appearance of new types of DSS such as web-based DSS [2], Mobile DSS [3], Knowledge Based DSS [4], and ubiquitous DSS [5]. Despite the research progress made on DSS architectures, these systems are still not responding to the dynamic relation between the system and the user. There is a need for a non-static decision support system: a decision support system should be in a dynamic relation with the user. This dynamic relation can be ensured by capturing user's environment, understanding the context and providing decision support according to his/her situation. Based on representation-bridging communication technics as defined on cognitive infocommunication research field [20] [21], the set of knowledge have to be presented in a structured way that a simple decision support system cannot provide.

In this paper, an approach for knowledge structuring will be discussed. The aim of this approach is to respond to every actor needs in the factory according to the current working situation and depending on cognitive parameters. The proposed concept will be a part of research issue in the proposition of "Digital Factory Assistant" [6] [7].

At first, we will discuss some related works. Then, we explain our research proposal and its context. The third part will expose different points token into account through the cognitive based approach. Before the conclusion, we made an overview of the use cases that will be used to validate our approaches.

II. Related Works

Many propositions related to factory actors assistance in the factory have been encountered in the literature. In a maintenance context, CARMMI model [15] provide support to operators during maintenance tasks through mixed reality providing information access from different sources. This model allows the acquisition and presentation of different data: CAx data, maintenance, and virtual data. From a decision making point of view, the big quantity of the information presented in the interface can reduce the efficiency of the operator to make the right decision. In fact, the interface contains augmented reality, visualization system, information and historical information data. The human machine interactions are not studied in this project.
A second work in the same context was presented by Toro [16]. A framework and a system implementation were developed for the exploitation of embedded knowledge in the domain of industrial maintenance. This framework uses a shared ontology designed to model and support pervasive computing applications called SOUPA. A knowledge

acquisition system is also developed in this project called Experience Knowledge Structure. This system extends the functionality of SOUPA in a way that formal decision events can be suggested to the user during the working process. Both of these two technologies were used to develop the UDKE system (User, Device, Knowledge, and Experience). The UDKE provide a conceptual model of a maintenance system that combines knowledge, user experience and Augmented Reality techniques. The context awareness notion was absent from this project and therefore, the possible decisions and information provided to the user were not relied to the current task and did not consider user's knowledge.

Kwon [17] [18] has developed a framework called ubiDSS. ubiDSS is a framework of multi-agent and context-aware based proactive decision support system. The architecture of this framework is composed by a number of subsystems: context subsystem, dialogue subsystem, knowledge subsystem, model management subsystem, and a database management subsystem. Even that the application field of the ubiDSS system is far from industry, it was very important to study the interactions between the components of its framework and the models behind.

Many other propositions were encountered in the literature relied to the human being assistance in the different product lifecycle stages, especially, in design process. However, the application of such propositions in manufacturing context is very rare. In fact, despite the diversity of these projects, few of them deal with human assistance in production systems at a "machine level" where information is less available comparing to other departments in the factory.

III. RESEARCH PROPOSAL

A. ARTUR project

Related to previous cited works, the ARTUR project aims to offer factory actors with a so called "Digital Factory Assistant". Through this assistant the operator will benefit from an omnipresent support along the manufacturing process.

The digital assistant restitutes knowledge from distributed knowledge sources and relies in more than one way of interaction with the user in order to act upon the task that the operator is doing by providing relevant information and decision support.

It consists of an advanced knowledge based system which allows knowledge access from different sources in the factory such as Product Lifecycle management (PLM) CAx models (Computer aided Design/ Manufacturing/engineering CAD/CAE/CAM…), material flows, process chains, and simulation data. The basic idea is to allow each person to be able to respond on any given situation, mainly thanks to high speed simulation and performance evaluation models and methods.

B. Scientific propositions

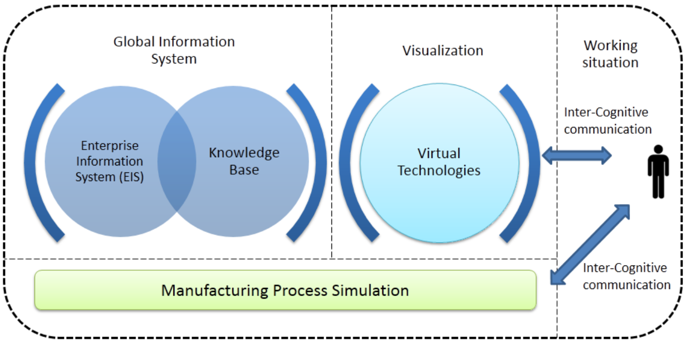

Fig. 1. ARTUR project

The vision about the "Digital Factory Assistant" is based on the concept of ubiquitous environments. Fig. 1 outlines the first conceptual architecture proposition of the digital assistant in a high level. The global architecture is based on four main units:

- The working situation module is an abstraction of the working situation. This module is related to the human-machine level, where contextual information related to user's working situation can be acquired.
- The second unit is related to the issue of coupling knowledge models with the information system in the factory. This coupling aims to ensure a better reuse of the entire knowledge resides on the factory through multiple sources. Cognitive infocommunication is defined as the communication capability between two actors where the cognitive processes can co-evolve with infocommunication devices [19]. Based on an inter-cognitive infocommunication, the factory actor will interact with the system through a cognitive infocommunication interface.
- The advantage behind implementing advanced numerical simulation of the manufacturing process is to guarantee a better understanding and control of the process. Thanks to this simulation, the user can manipulate some parameters related to the process and anticipate the outcome of such manipulation on the simulated process before committing on the real manufacturing process.
- The last part deal with the problem of information representation. Virtual technologies will be used to propose a better restitution of the information. We can imagine a process of relevant information projection on the product itself or in the machine.

Combining all these aspects to work together is the real issue of the project. Dealing with the particular problem of linking knowledge parts with the whole information system in the factory, and to build our "Digital Factory Assistant" model, we have to consider many points of view and to deal with technological and modeling constraints. In the following section we will try to detail some of them.

IV. Building the Assistant Model

A. Context awareness

Situation awareness has been defined in the cognitive sciences as an intermediate state in the decision-making process of dynamic systems where the system should be able to understand the situation in order to make an appropriate decision for future development [8]. The situation-awareness [9] is a particular aspect of context awareness information systems. Context-aware systems have the particularity of anticipating the user's needs in a particular situation and act proactively to provide appropriate assistance. These systems relied on the notion of context. Dey [10] defined this notion as any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that considered relevant to the interaction between the user and the application, including the user and the applications themselves.

The human being has a central role in the working situation. Therefore, some works relied on the concept of user profiling [12] in order to achieve a comprehensive abstraction of contextual information about the user.

Thus, we can affirm that a context-aware system is a system that uses the contextual information to provide relevant information/service. Based on context definitions the assistant model should respond to three main features: understand the user's context, extract the relevant set of information and provide the user with the right information. To validate the ubiquity [11] in the desired model, the assistant should execute automatic work on background. The automatic execution of some tasks is based on already known contextual information, for example, user experience or current executed task. To do so, algorithms will be implemented to act like sensors in the manufacturing environment and detect contextual information.

B. Human-Computer interactions

The human computer interactions issue is decomposed on two parts. The first part is related on ergonomic issue that will be studied by other members of ARTUR project described in the second section. The second part is related to the way that information will be presented to the user.

As we described previously, contextual information will be extracted from manufacturing environment. These information will be used to extract the appropriate information related to the decision support process. The set of relevant information should be presented in a structured way and should not be the same for every user. The infocommunication interface that we aim to build will interact with the user in an intelligent way. This cognitive infocommunication interface will take into account the information "quantity" to be presented. This quantity will depend on already known contextual information and precisely user experience. According to this cognitive approach, the information quantity will be different from a beginner operator to an expert operator. In a context of uncertainty, the system will transfer a small amount of knowledge to a beginner user and led him, as his/her needs, to a larger amount of knowledge and do the opposite for a more expert user. This intelligent information exploitation system will be deployed in mobile device to make the information available in any context, even in complex working situations.

The knowledge visualization model that we aim to design should take the psychological aspects into account and reflects the fact that the interactions between factory actors assistance tools and their working environment have a significant impact on knowledge acquisition and consequently their role is vital in order to improve efficiency in production systems.

C. Cognitive-based Knowledge structuring approach issues

Foundations of our research work relate to a new proposition for modeling and structuring information, and more generally knowledge [6]. We believe that the set of knowledge in the factory should be structured in a multi-scale way. Where every scale is corresponding to a set of knowledge that should be given to a user according to cognitive related parameters such as user level of expertise in a domain or in a task. Like in video games, the user will not just "play" in his/her level but, s/he can "jump" to another one according to his/her needs and if s/he feels that s/he is well mastering the existent set of knowledge in his/her level.

This cognitive approach is related on some concepts mainly the granularity of knowledge [13] [14]. The concept of knowledge granularity is based on dividing the set of knowledge into pieces. Generally speaking, granularity can be defined as the possibility to represent and operate on different levels of detail in data structures.

By proposing to apply this concept on the knowledge set, we aim to structure, in a granular way, the whole knowledge sources and match it with different knowledge domains combined in the manufacturing field by factory actors by granular reasoning. This process of knowledge granularity structuring is presented in Fig.2.

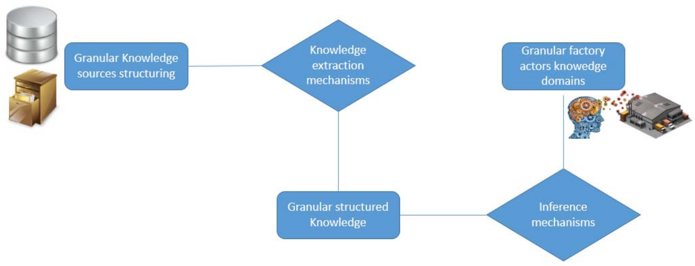

Fig. 2. Process of knowlegde granularity structuring

Our assistant will be based on a dynamic knowledge representation: in a process of decision making, the actor will combine different types of data and knowledge available in various forms. This knowledge set can be decomposed into hierarchical structure and represented in a multi-level way. According to his/her needs, the user will look for more granular set of knowledge that satisfies his/her query.

At first, we will define knowledge acquisition mechanisms that will be coupled with other mechanisms for context interpretation. The output of this level will be used to construct the knowledge structure and accordingly the multi-scale representation of the knowledge set.

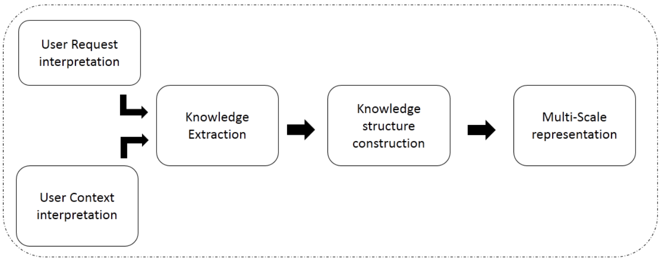

Fig. 3. Context-aware knowledge structuring process

Fig.2 shows the different subsystems handling the knowledge structuring process. The role of user request and user context interpretation subsystems is to understand the user's need and get relevant contextual information respectively. After knowing the user request and the context of the current working situation, these subsystems will be the input for the knowledge extraction subsystem. The output will be unstructured relevant knowledge. Structuring the set of knowledge is the role of the next subsystem. The knowledge visualization mechanism will extract the already structured set of knowledge and present it to knowledge consumers in a multi-scale way.

Contextual information will be extracted from user profile and the working environment. These contextual information will be used as cognitive parameters to be injected to the assistant model. The most important contextual parameters can be:

- Experience Level: the factory actor will receive the information according to his/her experience level. This parameter can be extracted from information system like Enterprise Resource Planning (ERP) or human resource systems used by some industries to manage their human capitals.
- Activity: this parameter determines the task that the user is doing. By knowing what is the current activity exercised by the user, we can distinguish between activities that demand a decision to take or not and providing information according to the current task.
- Location: determine the location of the user, in which department he is working or in which part of the production line.
- Time: the time can correspond to the needed time for performing the task or to take the decision. This parameter determines if the user does need a quick response or not to make his/her decision?
- Relations: according to the user's task, the system can search and propose "knowers" that have more experience than the current user.

These contextual information will be extracted by the context interpretation subsystem and consumed by the knowledge extraction mechanism in order to extract relevant knowledge according to them.

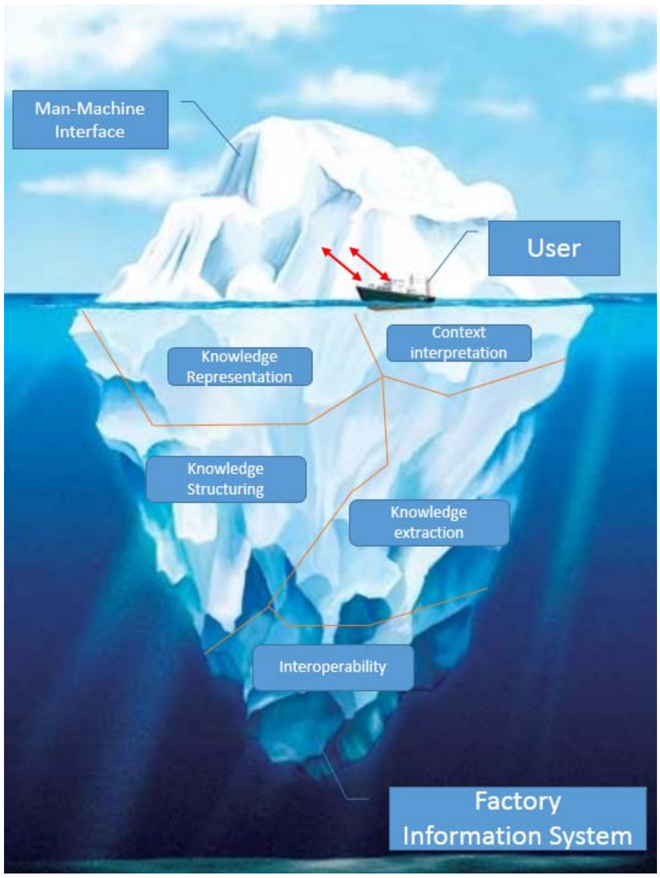

Fig. 4. Global illustration of the cognitive knowledge structuring approach

Fig.3 summarizes foundations of our research work. This illustration outlines the difficulties and issues related to the proposition of the digital factory assistant. In fact, the user will deal with only the end-user dedicated infocommunication interface and virtual reality technology, compared as the top part of an iceberg. "Back-end" problems are represented by the lower part of the iceberg. Actually, based on knowledge extraction mechanisms, the assistant will interact with the existing information system in the factory which creates interoperability problems between the desired architecture and the existing one. Another problem is structuring the set of extracted information in order to fit with the cognitive based knowledge structuring assumption and the desired interface for intelligent knowledge visualization. The last problem is related to the context handling. This issue is decomposed on two parts: contextual information detection and contextual information interpretation.

These scientific constraints will be joined with industrial constraints. Through a use case we will try to validate our approach in the real world and combine real issues. In the next section we present an overview of the industrial use case.

V. CURRENT WORK

To validate our proposition, we will be based on two use cases from aeronautic industry. The tasks during the study of the use cases are as following:

- Process observation: This task helps us to know what different actions that the factory actors are doing and to analyze how the actor resolve different problems in front of his/her machine from a cognitive point of view by answering to the questions: what are the different token decisions along the process execution? What are the used tools?
- Technical documentation analyzing: Besides, the tacit knowledge hold by factory actors, the explicit knowledge is stored in different technical documentation related to process and the developed product. In most of cases, this knowledge is just stored in some place in the factory and they are not well exploited.
- Information system audit: the aim of this task is to identify the different sources of knowledge stored in factory information system especially in PLM software and other applications directly related to the process.

These tasks allow us to set up cartography of different knowledge domains and to build a map of different knowledge sources in the factory. For confidential reasons we cannot describe the use case. Based on the study of our use case, the next step of our work is to build the information model and set up knowledge extraction mechanisms from knowledge sources in the information system. The main issue of our work is to find which information to give to the operator, where, when, and how.

A more detailed version of the global proposition architecture will be established including the different Man-Machine and Machine-Machine interactions.

VI. CONCLUSION

In a production system, the user may be faced with different working situations that require different decisions to take. Based on a cognitive approach, we aim to design and implement a framework that interacts with the information system in the factory in order to extract relevant information and present them in a multi-scale structure through a cognitive infocommunication interface. In this paper, we presented an overview about the proposed approach and the different scientific locks.

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