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# Multi-scale knowledge structuring: Towards an ubiquitous assistant for the factory of the future

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**Abstract.** The research project described in this paper deals with the problematic of structuring and exploiting enterprise's knowledge. Manufacturing knowledge is obtaining more and more vital position as a key success of the factory. The vision to maximize the benefits from knowledge management practices in production environments is shared between both industrial and research communities. We propose in this work a new approach for knowledge structuring. The approach proposes to structure the knowledge into multi-scales where each scale represents a completeness degree. Taking into account in which context the knowledge should be reused is a gap often neglected in the existing knowledge based systems. Therefore, we propose a context model aiming to capture and manage contextual information about the working environment. In addition, a conceptual framework has been proposed in order to adapt the knowledge set to the current context where it is reused.

**Keywords:** Knowledge Management, Knowledge engineering, Context-awareness, ubiquitous computing, Factory of the future.

## 1 Problem statement and research questions

Recent visions for the factory of the future highlight the importance of integrating the pillars of knowledge management and engineering in the whole manufacturing divisions involved in the product lifecycle development (Westkämper, 2014). Manufacturing knowledge is obtaining more and more a vital position as a key success of the factory. The continuously changing landscape of today's factory leads managers to focus on new ways to manage with more efficiency their production systems. This need for the adoption of new industrial practices is combined with the technological evolution coming with the new ICT trends. In fact, the increasing usage of ICT tools in the factory coming with the digital (PLM, ERP, MES, etc.) and smart (IoT, RFID, Wi-Fi, etc.) manufacturing paradigms contributes to this vision with the aim of supporting factory workers in conducting better production outcomes.

The usage of knowledge-based systems to support manufacturing activities has been emerged as an appropriate solution to deal with the complex activities in production lines such as planning, control and optimization. These systems have been designed and implemented with the objective of assisting factory actors. Even though

that these tools showed their ability to assist different workers' tasks, the amount of data they generate during the product lifecycle development, from the emergence of the idea to the after sales service activities management, is exponentially increasing. According to (Landherr et al., 2012), in order to tackle this problem, the full potential of knowledge management should be tapped and more sophisticated and intelligent management approaches of enterprise's knowledge have to be proposed.

The expansion of ICT tools usage the manufacturing domain results data and information overflow making the handling of the access to the exact needed information more and more complex. According to (Farhoomand et al., 2002), the challenge for knowledge-based systems is to support tailoring and summarizing of information collected from massive, heterogeneous and distributed sources depending on user needs.

In order to overcome these issues, we estimate that a knowledge based system has to forward and structure the knowledge in a proper format that corresponds to its consumer ability to perceive it. This means that the information has to be understandable and its meaning has to be easy to interpret. The assimilation of the information do not depends only on how it has been forwarded to the user but also his/her maturity level comes into play. Therefore, knowledge should be modeled and formalized by taking into account this important requirement. Furthermore, having access to a knowledge set depends not only on the expertise level but also on multiple parameters such as the activity, the role, etc. These parameters should be presented explicitly and managed (captured, inferred, stored, etc.) separately from knowledge in order to guarantee a contextual reuse of the latter. The contribution of this research work put forward a context-aware conceptual framework aiming to respond to different working situations (Houssin et al. 2006 ) that a worker may encounter in his/her daily activities. The framework can be plugged to knowledge based systems or other information systems used in the factory to enhance the awareness of their users regarding each activity they are doing.

Based on the problem statement outlined in the previous section, research questions to be investigated in this work are:

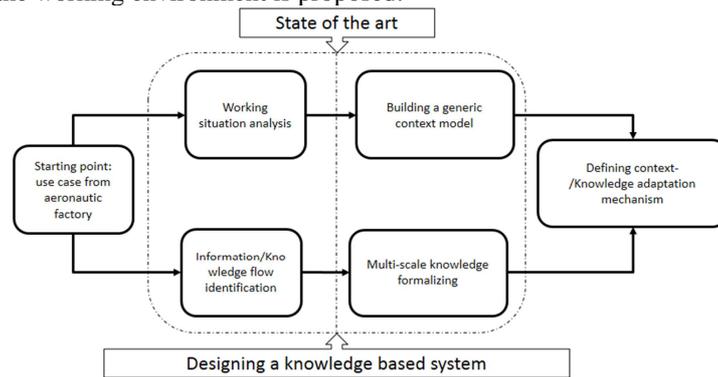
- How to structure the enterprise knowledge set in order to enhance its reuse for supporting daily working activities and decision-making purposes?
- How to define and model the context in working environments?
- How to capture the context and address, according to it, the appropriate knowledge to the worker?

The work plan that describes how these questions will be addressed is described in the next section.

## **2 Work plan**

The work plan adopted in this paper is illustrated in Figure 1 below. Scientific gaps identified in the previous section has been confirmed through an extensive state of the art about different research fields involved (Knowledge management, context-awareness, ubiquitous computing, etc.). A production line of aircraft fuselage has been a starting point of our research study. This "in-vivo" working field study allows

us to take stoke of the real need to enhance knowledge rooting at workplace. After that, a generic context model is proposed. The aim of this model is to capture and manage contextual information about the working activities. The next step consists of formalizing the knowledge set being identified according to a multi-scale approach. Then, a mechanism to adapt each knowledge set to a unique captured context occurred in the working environment is proposed.



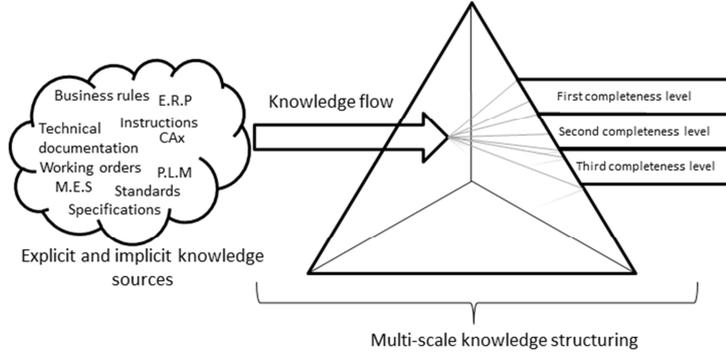
**Fig. 1.** Adopted work plan.

The last phase consists of building a knowledge-based system that implements the global proposed approach.

### 3 Results and discussions

#### 3.1 Multi-scale knowledge structuring approach

Acquiring more knowledge about a manufacturing process in less time is a big challenge for factory actors particularly for novice workers. The aim of our research work is to develop a cognitive based methodology in order to enhance the learning process. This approach is based on cognitive structuring of the knowledge set related to all the concepts in factory. As shown in Figure 2 the approach is acting like a prism dividing the knowledge set, all sources included, into three completeness-based layers.



**Fig. 2.** Illustration of the multi-scale knowledge structuring approach.

In the context of the continuous challenging environment that today's enterprises are experiencing, knowledge reuse plays a major role in enhancing workers training and their decision-making abilities. For this work, we propose an approach in order to structure the knowledge set into multiple scales. The approach is based on the hypothesis that knowledge can be comprised of three levels. Each level translates a completeness level of an activity domain in the factory. We consider that the knowledge can be represented as a collection that incorporates the knowledge about the product, the process, and the resources used. This decomposition is inspired from models found in the literature mainly UEML (Vernadat et al., 2002) and FBS PPRE (Labrousse et al., 2004). The knowledge  $K_i$  is a triplet:

$$K_i = \langle KP_i | KPr_i | KR_i \rangle$$

Where  $KP_i$ ,  $KPr_i$  and  $KR_i$  represent respectively the knowledge subset about the products, processes and resources. A knowledge base that encompasses these knowledge fragments can be represented by the set:

$$KB = \{K_i, i \in (1..n)\}$$

With respect to the multi-scale structuring hypothesis, the knowledge base can be organized in three completeness levels:

$$KB = \{K_i^j, i \in (1..n), j \in (1..3)\}$$

The multi-scaled knowledge base that implements this approach intends to store and to formalize different forms of knowledge. In fact, the approach requires integrating tacit knowledge into the assistant system by formalizing expert knowledge and explicit knowledge. This is done by giving access to the existing knowledge and information that can be already stored in some ICT solutions (ERP, PLM, MES, etc.) (Nonaka, 1995). The scientific backbone of the approach is that this multi-scaling can enhance the learning process in working places and helps the workers to acquire more knowledge about the activity that he/she is performing in an implicit way. In addition, this approach can reduce the information overload by giving the beginner, intermediate and expert workers the appropriate amount of the knowledge set.

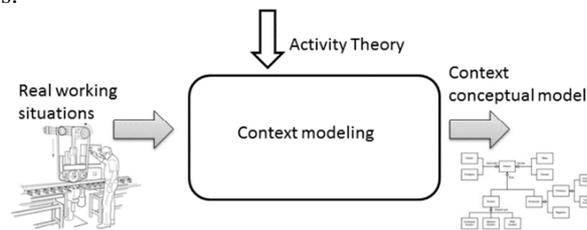
The main purpose of the proposed structuring approach is to provide each actor in the factory with access to the appropriate set of knowledge according to his/her expertise level. However, having access to this knowledge base depends not only on the expertise level but also on multiple parameters such as the activity, the role, etc.

These parameters should be presented explicitly and managed (captured, inferred, stored, etc.) separately from the knowledge base. In computer science and mainly ubiquitous computing (Weiser, 1991), this set of parameters is labeled as ‘context’.

### 3.2 Modelling and formalizing the context in working environment

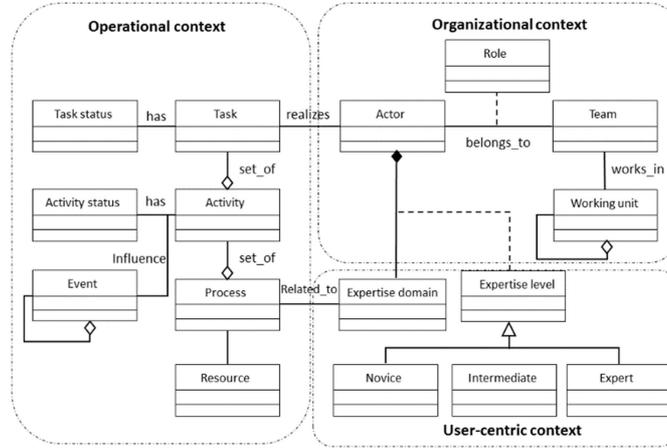
The concept of ubiquitous computing is based on the vision that computers will be deeply incorporated into our daily life until they “disappear” (Weiser, 1991). Computer technology can be considered as ubiquitous if it anticipates user needs in a normal or particular situation and acts proactively to provide the appropriate information or assistance. The context-awareness is considered as a core feature of ubiquitous computing. It relies on the context notion with the aim of increasing the ubiquitous system capabilities in order to adapt the services they provide. The context notion was developed in the work of (Schilit et al., 1994) to outline how the context can be used to adapt the information according to the situation of the user. The most accepted definition of a context is that “*the context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between the user and the application, including the user and the applications themselves*” (Dey, 2001).

Based on a large literature survey on context models, we concluded in (Dhuieb et al., 2015) that an important shortcoming is that context models are not generic. This fact may have an influence on the system ability to perceive the current context of its user. Therefore, we proposed as showed in Figure 3 to use the Activity Theory (AT) introduced in cognitive science by (Engeström Y., 1987) as a support for our context modeling process.



**Fig. 3.** Context modelling based on activity theory.

The main idea behind the activity theory (AT) is to set up a theoretical and descriptive tool aiming to analyze and understand the activity independently from a specific domain of application. Each activity in AT is performed by a “Subject” aiming to transform an “Object” into “Outcome” by means of “Tools” and through a “Transformation process”. The object is shared in a “Community” and mediated by “Rules”. The “Division of labour” mediates the relationship between the “Subject” and the “Community” in one hand and between the “Community” and the “Object” in the other hand. The “Rules” in AT consist of social rules relating people to each other in a “community” (Engeström Y., 1987).



**Fig. 4.** Proposed context model.

The proposed context model (Figure 4) is based on the foundations of activity theory and built according to three different points of view: operational, organizational and user-centric dimensions of context:

- Operational context: this dimension is related to the activity of the worker. The process is decomposed into a set of activities that can be in turn divided into a multiple numbers of tasks. The aim of the operational view of the context is to determine, at execution time, in which process, activity and task the worker is involved.
- Organizational context: the organizational context is intended to determine the context of the worker among the factory life from organizational point of view. This helps the system to know: to which team belongs the worker and what is his/her exact role in this team? Inferring such related information allows the association an organizational degree of freedom to each worker.
- User-centric context: the user-centric dimension of context elements is related to the user profile. The user is defined through a set of context parameters describing mainly his/her competency profile and characterizes the knowledge domain of the system user.

The context model is used to structure a context repository that includes all the situations that may occur in the working environment.

### 3.3 Towards an ubiquitous assistant for factory stakeholders

After presenting the main idea behind the multi-scale knowledge structuring approach and the context model used in this work, this part of the paper will points out the conceptual framework proposed to handle the ubiquitous knowledge reuse process. We called this framework (Figure 5) the context-knowledge adaptation engine since it aims to extract the knowledge set that fits with a given user context.

The reference architecture of the adaptation engine is designed following Service Oriented Architecture (SOA) principles. The objective behind this choice is to allow a knowledge based system developed under this adaptation engine to be easily “plugged” with other IT systems in the factory.

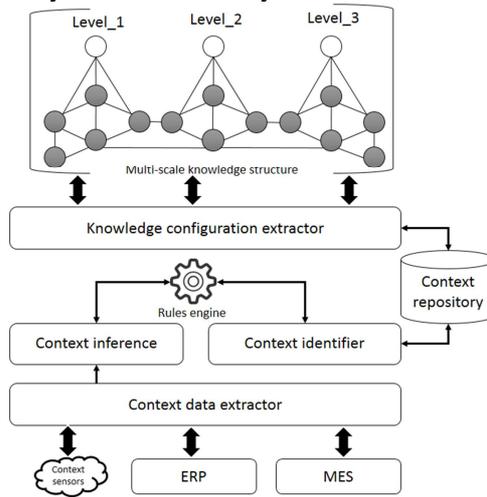


Fig. 5. Conceptual framework for context-knowledge adaptation.

Context-awareness is achieved by different components that support the management of context information. The role of the context data extractor component is to extract the context data from context sensors and different existing IT systems. The context data extractor aims at this level to extract such information and update the context model. Once the context data are gathered, the context inference process consists of applying inference stored rules in order to generate other additional context information about the current situation. The context identifier aims to zero in on the context recognition. This means to compare different context elements being extracted and inferred with other situations stored in the context repository.

At the next stage of the adaptation process, the knowledge configuration extractor aims to extract the relevant knowledge set to a given context. Therefore, this component takes a situation as input and forward knowledge set configuration according to it as output. With respect to Weiser’s vision about ubiquitous computing, this adaptation process has to be invisible to the user. The knowledge forwarding has to be proactive as much as possible.

#### 4 Conclusion and current work

When the question about how the factory of the future will be conducted is raised, the importance of giving more emphasis to the role of the human being is discussed. The positioning of the human being as a key driver for better factory performance has been pointed out by many visions and roadmaps about the factory of the future. We

believe that advanced assistance tools have to be developed in order to enhance the workforce performance in managing day to day tasks.

The research proposal reported in this paper highlights the significance of context elicitation and modeling in handling the access to manufacturing knowledge. A multi-scale based approach has been introduced to structure the manufacturing knowledge set according to different completeness levels. The approach introduced here meets the challenge of forwarding context-aware knowledge to factory stakeholders and reducing the information overflow by giving the exact needed ones in the appropriate format. Current work is focusing on the implementation of the assistant system supporting the proposed approach.

## 5 Acknowledgment

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